

PUBLICLY AVAILABLE SPECIFICATION



Zhaga interface specification book 1 and book 7

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PUBLICLY AVAILABLE SPECIFICATION



Zhaga interface specification book 1 and book 7

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ZHAGA INTERFACE SPECIFICATION BOOK 1 AND BOOK 7

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The document layout, terms and definitions, etc. within this PAS therefore do not follow the normal IEC drafting rules that would be applied for an International Standard.

Subdivision 1 comprises Zhaga Book 7 – Rectangular LED Module with undefined LES.

Subdivision 2 comprises Zhaga Book 1 – Overview and common information, which is essential to the interpretation of Zhaga Book 7 (and future Zhaga books).

The future intention is for the content of this PAS to be incorporated within one or more International Standards and at this time any conflict with IEC Directives and drafting rules will be addressed.

The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

Draft PAS	Report on voting
34A/2048/PAS	34A/2054/RVDPAS

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ZHAGA INTERFACE SPECIFICATION BOOK 1 AND BOOK 7

Subdivision 1

Zhaga Interface Specification Book 7 Rectangular LED Module with undefined LES

Summary (informative)

Background

The Zhaga Consortium is a global lighting-industry organization that aims to standardize LED light engines and associated components such as LED modules, holders and electronic control gear (LED drivers).

Zhaga has created a set of interface specifications, known as Books. Each Book defines an LED light engine and/or associated components by means of the mechanical, photometric, electrical, thermal, and control interfaces of the product to its environment. This makes such products interchangeable in the sense that it is easy to replace one product with another, even if they have been made by different manufacturers.

Contents

This book 7 defines several LED modules. Each LED module has a rectangular shape and the only restriction to the light emitting surface is that no light is emitted in the direction of the reference plane of the LED module.

This book must be read together with book 1, which is included as Subdivision 2 of this document.

Intended Use

The Book-7 LED module can be mounted in a luminaire, for example by means of screws. Book-7 LED modules are intended to be replaced by professionals only.

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1 General

1.1 Introduction

The Zhaga Consortium is a global organization that aims to standardize LED Light Engines and associated components. A LED Light Engine is a light source for general lighting that is based on solid state technology, and typically consists of one or more LEDs combined with an Electronic Control Gear. Examples of associated components are LED Modules, Electronic Control Gears, and Holders. Zhaga has created a set of interface specifications, known as Books defining interfaces between LED Light Engines, associated components and Luminaires.

Book 1 is a special Book in the sense that it provides common information, which is relevant to all other Books in the series. In addition, Book 1 defines requirements and compliance tests, which are applicable across multiple Zhaga books. Such Books refer to those requirements and compliance tests as applicable.

1.2 Scope (informative)

This Book 7 defines LED Modules, which can be fixed in a Luminaire. This document defines:

- Ten categories of the rectangular shaped LED Modules.
- Luminaires that provide the appropriate environment for the Book-7 LED Module(s).

Book 7 LED Modules are intended to be installed and replaced by Luminaire manufacturers only. Book 1 is included as Subdivision 2 of this document.

1.3 Conformance and References

1.3.1 Conformance

All provisions in the Zhaga interface Specification are mandatory, unless specifically indicated as recommended, optional or informative. Verbal expressions of provisions in the Zhaga Interface Specification follow the rules provided in Annex H of ISO/IEC Directives, Part 2:2011. For clarity, the word “shall” indicates a requirement that is to be followed strictly in order to conform to the Zhaga Interface Specification, and from which no deviation is permitted. The word “should” indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited. The word “may” indicates a course of action permissible within the limits of the Zhaga Interface Specification. The word “can” indicates a possibility or capability, whether material, physical or causal.

1.3.2 References

For references that are not listed in this section, see [Book 1]. For undated references, the most recently published edition applies.

[Book 1]	Zhaga Interface Specification, Book 1: Overview and Common Information. Book 1 is included as Subdivision 2 of this document.
[ISO/IEC 15948]	Information technology – Computer graphics and image processing – Portable Network Graphics (PNG): Functional specification.
[IEC 60598-1]	Luminaires – Part 1: General requirements and tests
[LEDset-Inf]	LEDset1 Information Interface Specification, Edition 1.2, November, 2016 available from md-sig.org.
[LEDset-Pow]	LEDset Power Interface Specification, Edition 1.1, November, 2016 available from md-sig.org.

1.4 Definitions

This section defines terms that have a specific meaning in the context of this Book 7. Terms that have a specific meaning across all Zhaga Books are defined in [Book 1].

Book-7 LED Module LED Module according to the specifications in this book.

Uniformity Test Diffuser	Diffuser plate that is used for measuring luminance uniformity.
LED Module Demarcation	The mechanical boundary between a LED Module and its environment consisting of a Luminaire and interconnect.

1.5 Acronyms

This section defines acronyms that have a specific meaning in the context of this Book 7. Acronyms that have a specific meaning across all Zhaga Books are defined in [Book 1].

UTD	Uniformity Test Diffuser
-----	--------------------------

1.6 Symbols

This section defines symbols that have a specific meaning in the context of this Book 7. Symbols that have a specific meaning across all Zhaga Books defined in [Book 1].

d_{UTD}	Distance between the mounting plate and the UTD (unit: mm).
t_p	Temperature at a specific point on the LED Module (unit: °C).
$t_{p,\text{normal}}$	Value of the temperature t_p at normal operating conditions (see section 8.3.1; unit: °C).
$t_{p,\text{rated}}$	Value of the temperature t_p at which the Rated LED Module values are specified (unit: °C).
$t_{p,\text{headroom}}$	$= t_{p,\text{rated}} - t_{p,\text{normal}}$ (unit: °C).

1.7 Conventions

This section defines the notations and conventions used in the Zhaga Interface Specifications.

1.7.1 Precedence

In the case of any perceived discrepancy between the definitions provided in Part 1 of this document, Interface Definition and the definitions provided in Part 2 of this document, Compliance Testing, the definitions provided in Part 2 take precedence over the definitions provided in Part 1.

1.7.2 Cross references

Unless indicated otherwise, cross references to sections include the sub sections contained therein.

1.7.3 Informative text

Informative text is set in italics, unless the whole section is marked as informative.

1.7.4 Terms in capitals

Terms that have a specific meaning in the context of this Book 7 are capitalized. See section 1.4.

1.7.5 Units of physical quantities

Physical quantities are expressed in units of the International System of Units. All lengths that omit an explicit unit indication are in millimeters.

1.7.6 Decimal separator

The decimal separator is a comma.

1.7.7 Limits

Values that are indicated as typical, as well as values between parentheses, are informative.

2 System Overview (informative)

2.1 General

General information with respect to the Zhaga Interface Specifications and certification of products that comply with this Book 7 can be found in [Book 1], section 2.

2.2 Description of the LED Module

This Book 7 defines several categories of LED Modules. These LED Modules are intended to be mounted in a Luminaire. Figure 2-1 illustrates an example of an LED Module-Luminaire combination. In this example the Luminaire holds two LED Modules. In practice, a Luminaire may hold any number of LED Modules.

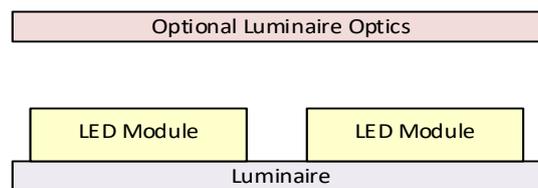


Figure 2-1: Example a Luminaire with two LED Modules

The Luminaire typically features Luminaire Optics which shape the light output of the LED Module(s). The photometric interface of the Book-7 LED Module is specified in such a way that using suitable Luminaire Optics, similar Luminaire performance is to be expected in typical applications using different LED Modules with the same luminance uniformity. The specification has been carefully evaluated to yield as much as possible “similar” performance without restricting the LED technology or the inner structure of the LED Module.

2.3 Outline of this Book

This Book 7 consists of two parts:

Part 1, Interface Definition, defines the LED Module-Luminaire interface in terms of the four sub interfaces:

- The mechanical interface (section 3).
- The photometric interface (section 4).
- The electrical interface (section 5).
- The thermal interface (section 6).

Part 2, Compliance Tests, defines:

- Specific tools, which are used for testing compliance of a LED Module or a Luminaire (section 7).
- The LED Module tests (section 8).
- The Luminaire tests (section 9).

The Annexes to this Book 7 provide the following additional information:

- Requirements on the information that shall be part of the Product Data Set (Annex A).
- Measurement of Luminance uniformity (Annex B)
- Guidelines for mechanical interface test (Annex C)
- History of changes (Annex D)

Part 1: Interface Definition

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3 Mechanical Interface

3.1 Drawing principles

For the purpose of this section, the provisions in [Book 1] - section 3.1, apply.

3.2 Mechanical references

The reference plane and the reference point of a LED Module, including (optional) TIM are defined in Figure 3-1. Dimensions are specified relative to either the reference point or the reference plane unless indicated otherwise. Moreover, dimensions are specified to include the thickness of the TIM (if present).

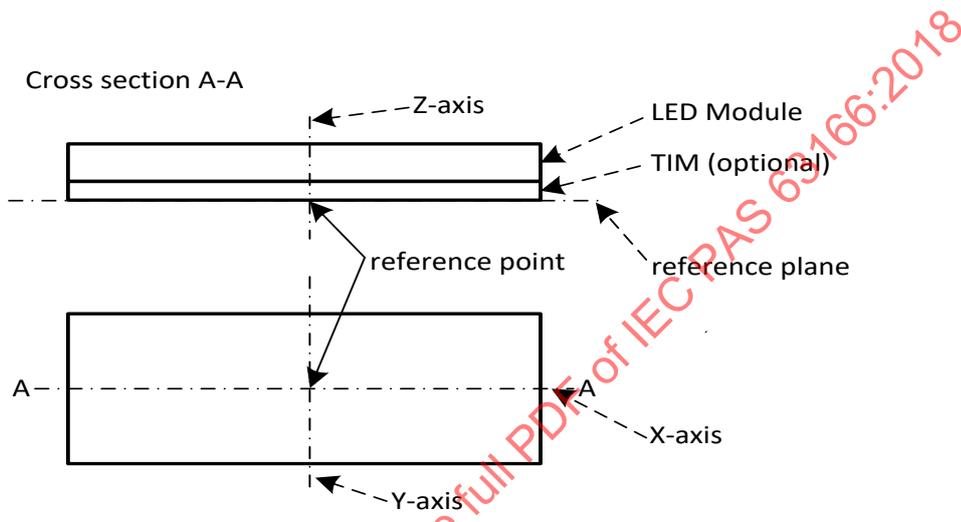


Figure 3-1: Positions of the reference point and the reference plane of the LED Module.

3.3 Book-7 LED Module categories

This Book 7 specifies a number of LED Module categories¹ that are identified by a designation. In the following sub sections, the LED Module Demarcations of these Book-7 LED Module categories are specified.

No part of a LED Module shall cross the outline boundaries of the corresponding LED Module Demarcation. And no part of a Luminaire shall cross the outline boundaries of the corresponding LED Module Demarcation.

Unless stated otherwise, all holes shall be available and for each hole at least 25% of the circumference of the hole shall be present in the LED Module.

In case the LED Module is applied in combination with a Thermal Interface Material, this material is defined to be part of the LED module. Thus the total height of the Module + TIM shall not exceed the maximum height H.

Additionally, for the purpose of this section, the provisions in [Book 1] - section 3.3, apply.

¹ Note that the LED Module demarcations not only define restrictions for the LED Module but also for the Luminaire.

3.3.1 L6W6

The LED Module Demarcation² of the L6W6 category is defined in Figure 3-2 and Table 3-1. The designation for this category is 'L6W6'.

dimension	Value
L	60
W	60
H	20
a	48
b	48
M	20
P	35
Øc	4,3

Table 3-1: LED Module Demarcation of the L6W6 category.

Notes to Figure 3-2:

- X-axis is symmetry axis for the outline and the mounting holes.
- Y-axis is symmetry axis for the outline and the mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

² In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

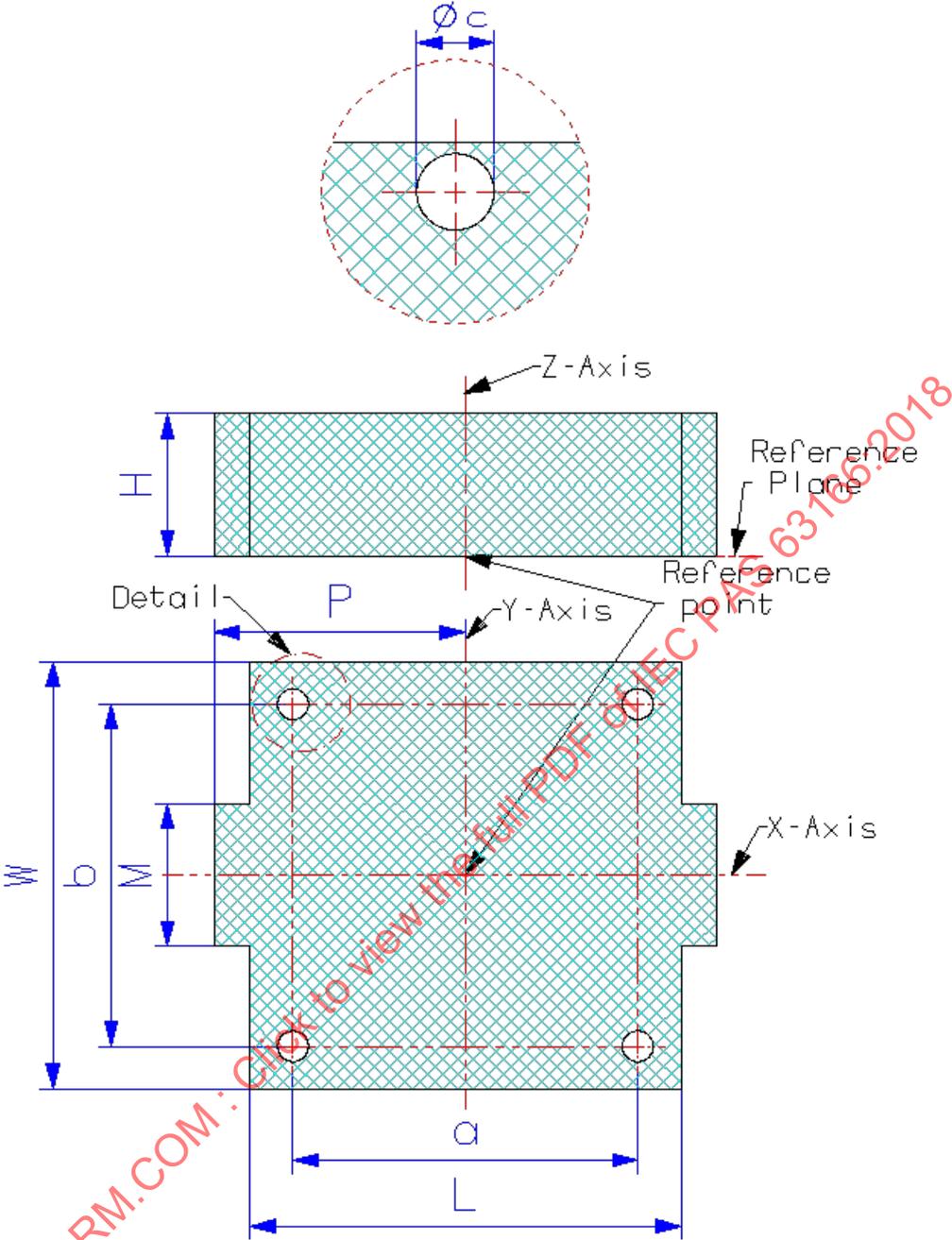


Figure 3-2: LED Module Demarcation of the L6W6 category.

The top figure shows the detail.

3.3.2 L14W2

The LED Module Demarcation³ of the L14W2 category is defined in Table 3-2 and Figure 3-3. The designation for this category is 'L14W2'.

dimension	Value
L	140
W	24
H	20
a	110
b	18,4
d	15
Øc	4,3

Table 3-2: LED Module Demarcation of the L14W2 category.

Notes to Figure 3-3:

- X-axis is symmetry axis for the outline and the cross-hair lines of the mounting holes.
- Y-axis is symmetry axis for the outline and mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

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³ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

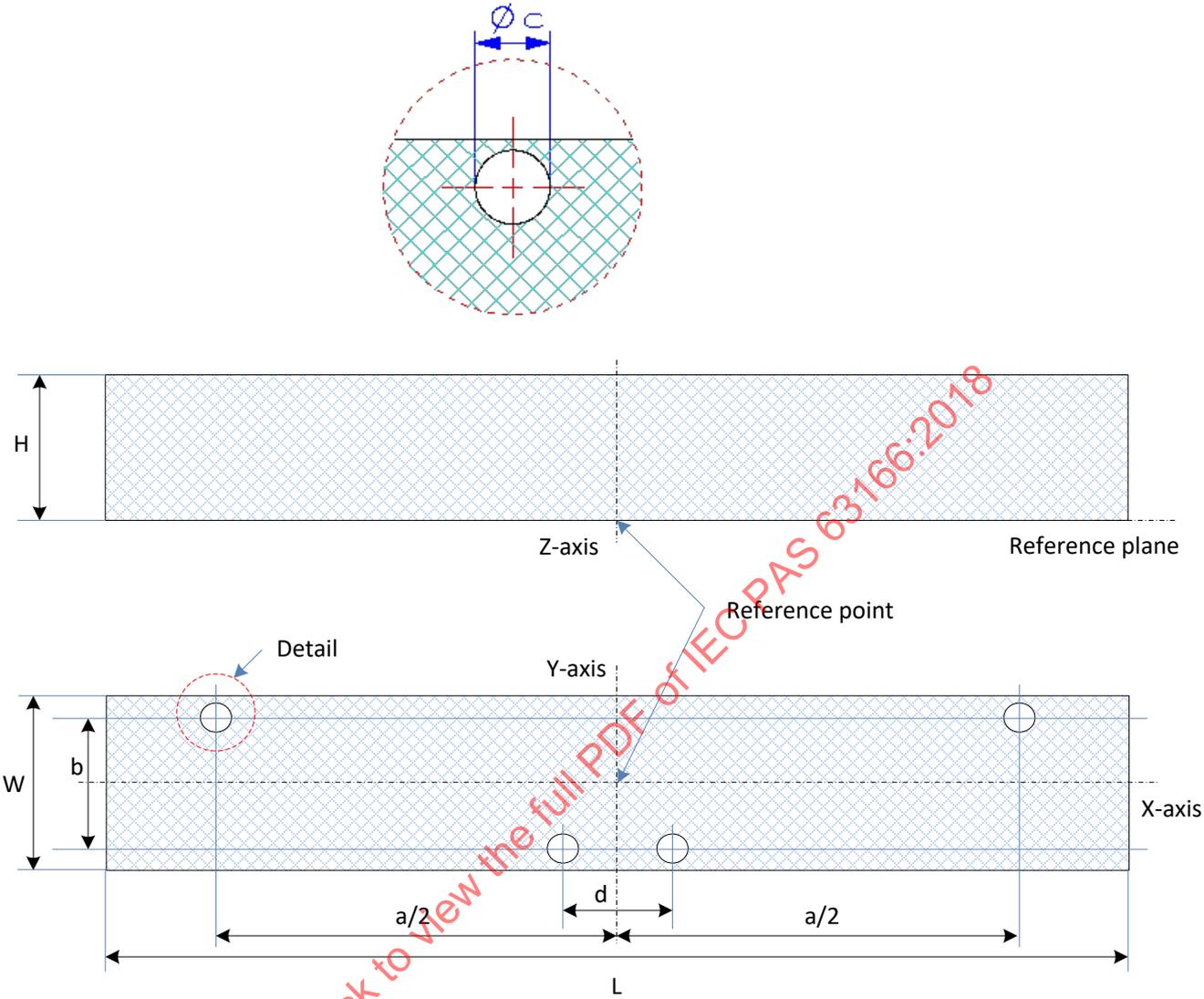


Figure 3-3: LED Module Demarcation of the L14W2 category.

The top figure shows the detail.

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3.3.3 L28W2

The LED Module Demarcation⁴ of the L28W2 category is defined in Figure 3-4 and Table 3-3. The two mounting holes at the bottom of the diagram of Figure 3-4 are optional for the LED Module but mandatory for the Luminaire. The designation for this category is 'L28W2'.

dimension	Value
L	280
W	24
H	20
a	125
b	18,4
Øc	4,3

Table 3-3: LED Module Demarcation of the L28W2 category.

Notes to Figure 3-4:

- X-axis is symmetry axis for the outline and the cross-hair lines of the mounting holes.
- Y-axis is symmetry axis for the outline and mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

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⁴ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

3.3.4 L28W4

The LED Module Demarcation⁵ of the L28W4 category is defined in Figure 3-5 and Table 3-4. The designation for this category is 'L28W4'.

dimension	Value
L	281
W	41
H	20
a	110
b	31
Øc	4,3

Table 3-4: LED Module Demarcation of the L28W4 category.

Notes to Figure 3-5:

- X-axis is symmetry axis for the outline and the cross-hair lines of the mounting holes.
- Y-axis is symmetry axis for the outline and mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

⁵ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

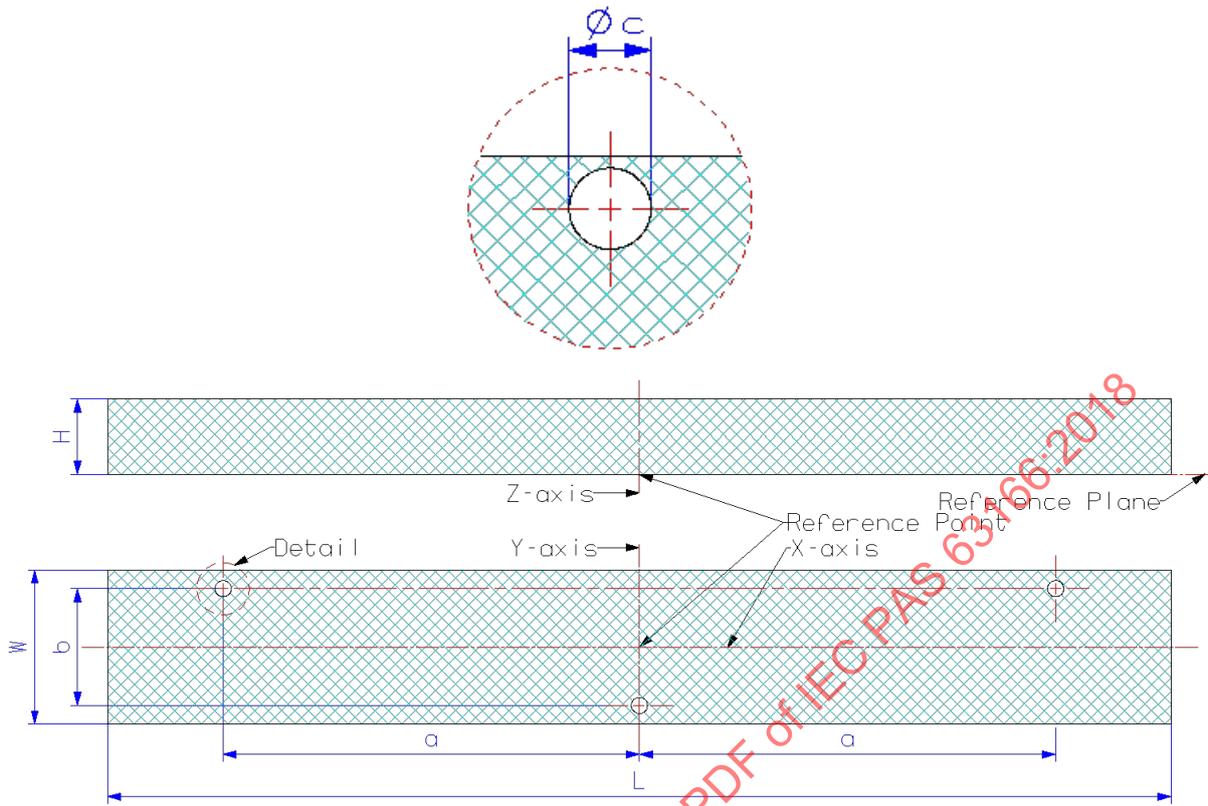


Figure 3-5: LED Module Demarcation of the L28W4 category.

The top figure shows the detail.

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3.3.5 L28W6

The LED Module Demarcation⁶ of the L28W6 category is defined in Figure 3-6 and Table 3-5. The designation for this category is 'L28W6'.

dimension	Value
L	281
W	61
H	20
a	91
b	40
Øc	4,3
d	11
e	15

Table 3-5: LED Module Demarcation of the L28W6 category.

Notes to Figure 3-6:

- X-axis is symmetry axis for the outline and the cross-hair lines of the mounting holes.
- Y-axis is symmetry axis for the outline and the left- and rightmost mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

⁶ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

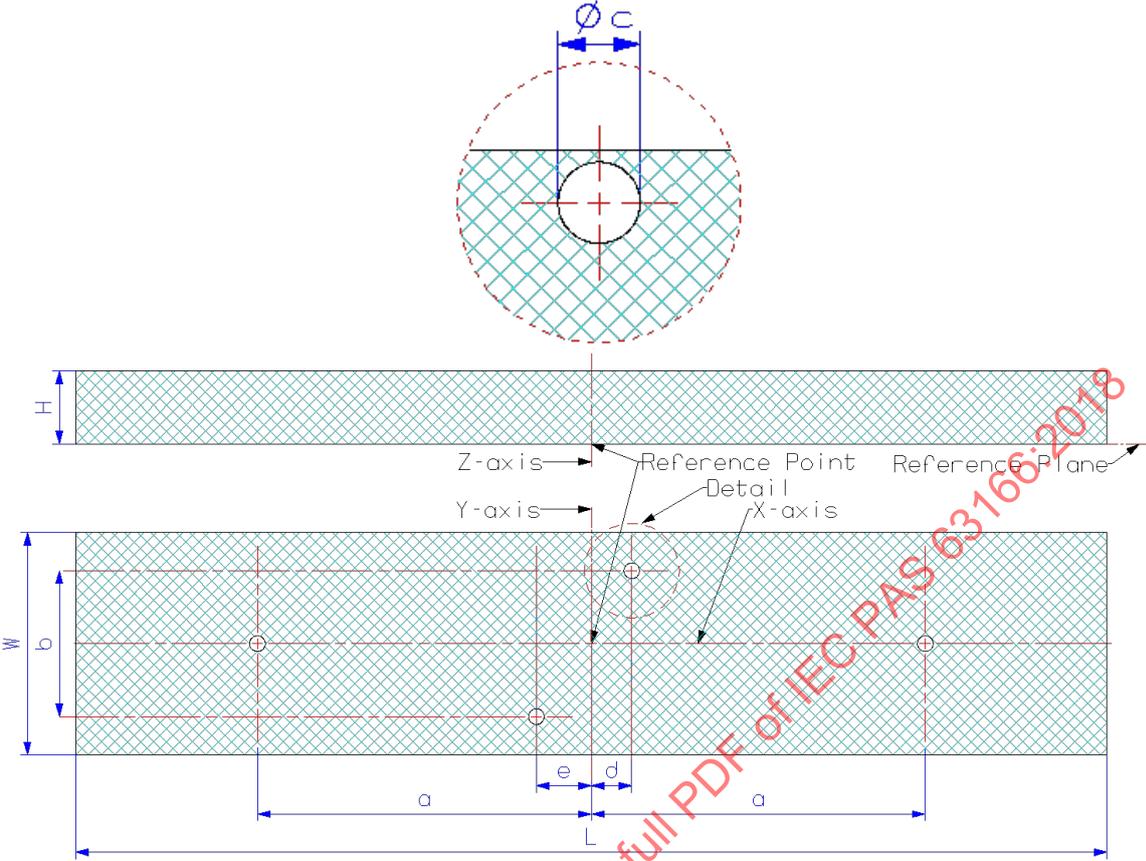


Figure 3-6: LED Module Demarcation of the L28W6 category.

The top figure shows the detail.

3.3.6 L28W28

The LED Module Demarcation⁷ of the L28W28 category is defined in Figure 3-7 and Table 3-6. The designation for this category is 'L28W28'.

dimension	Value
L	281
W	281
H	20
a	222
b	180
Øc	4,3

Table 3-6: LED Module Demarcation of the L28W28

Notes to Figure 3-7:

- X-axis is symmetry axis for the outline and the mounting holes.
- Y-axis is symmetry axis for the outline and the mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

⁷ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

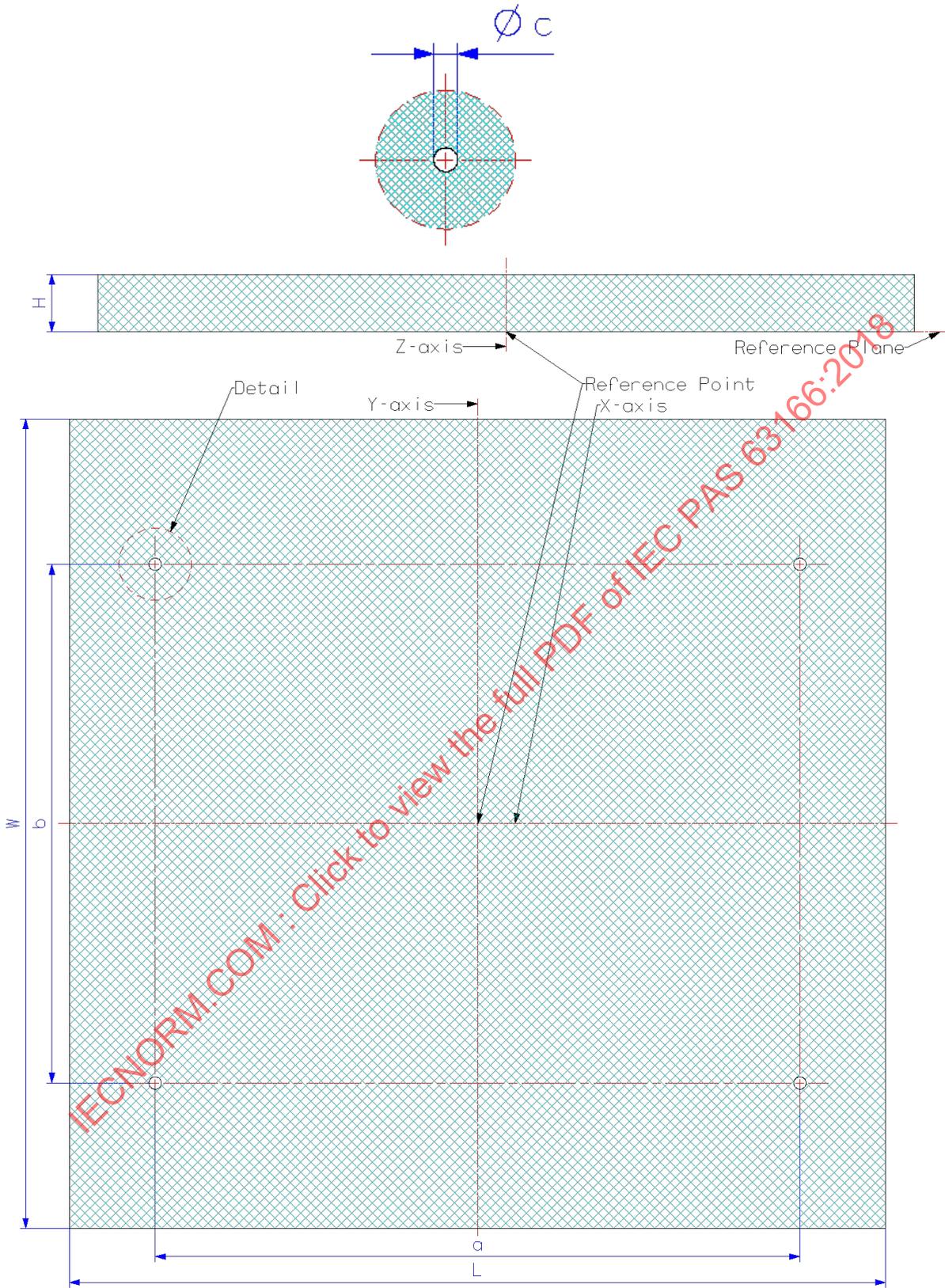


Figure 3-7: LED Module Demarcation of the L28W28 category.

The top figure shows the detail.

3.3.7 L38W38

The LED Module Demarcation⁸ of the L38W38 category is defined in Figure 3-8 and Table 3-8. The four mounting holes in the corners of the diagram of Figure 3-4 are mandatory for LED Module and Luminaire. The other mounting holes are optional for the LED Module but mandatory for the Luminaire. The designation for this category is ‘L38W38’.

dimension	Value
L	381
W	381
H	20
a	371,9
a1	21,3
b	67,2
Øc	4,3

Table 3-7: LED Module Demarcation of the L38W38 category.

Notes to Figure 3-8:

- X-axis is symmetry axis for the outline and the mounting holes.
- Y-axis is symmetry axis for the outline and the cross-hair lines of mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

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⁸ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

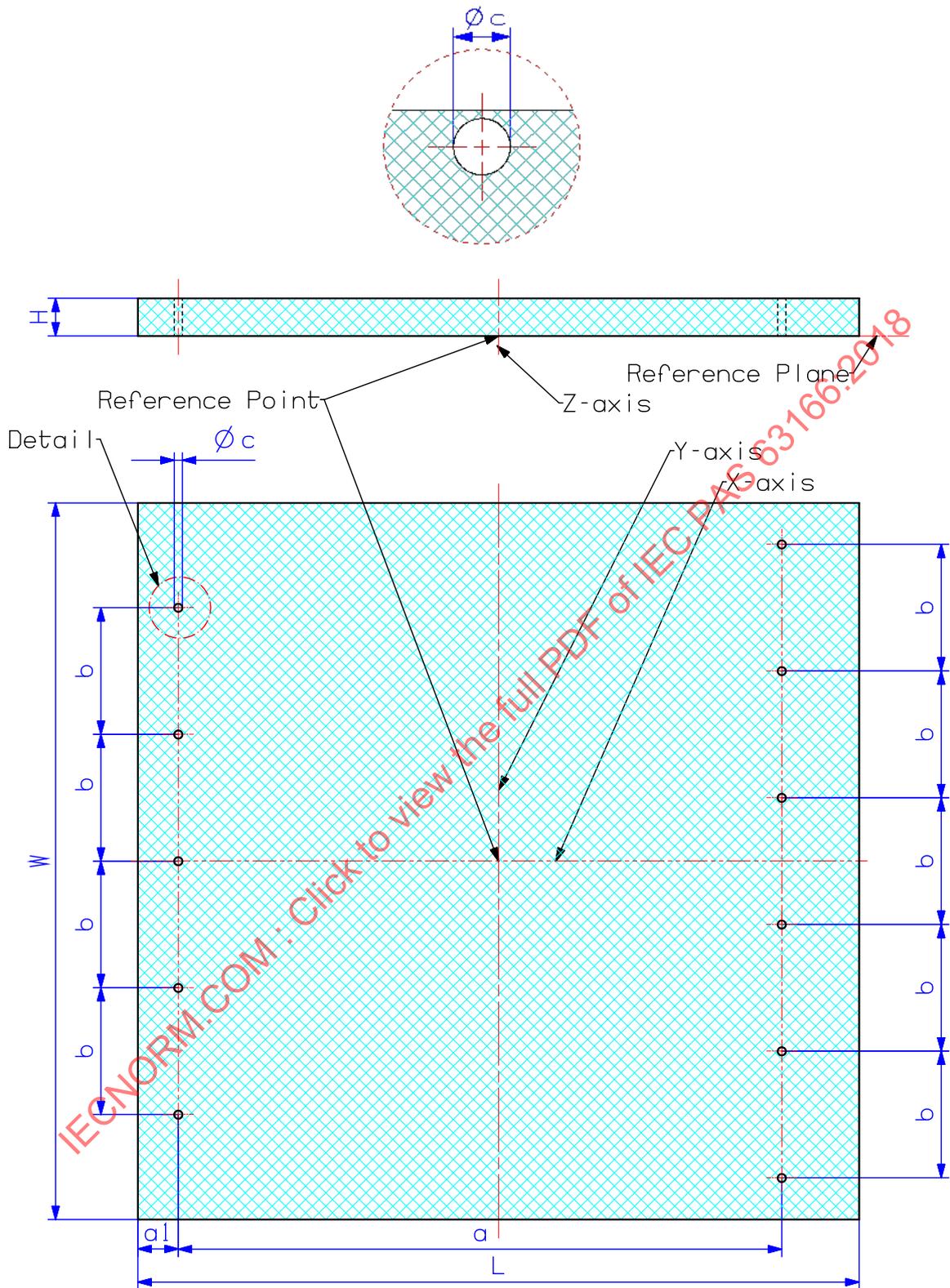


Figure 3-8: LED Module Demarcation of the L38W38 category.

The top figure shows the detail.

3.3.8 L56W56

The LED Module Demarcation⁹ of the L56W56 category is defined in Figure 3-9 and Table 3-8. The designation for this category is 'L56W56'.

dimension	Value
L	562
W	562
H	20
a	503
b	461
Øc	4,3

Table 3-8: LED Module Demarcation of the L56W56 category.

Notes to Figure 3-9:

- X-axis is symmetry axis for the outline and the mounting holes.
- Y-axis is symmetry axis for the outline and the mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

⁹ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

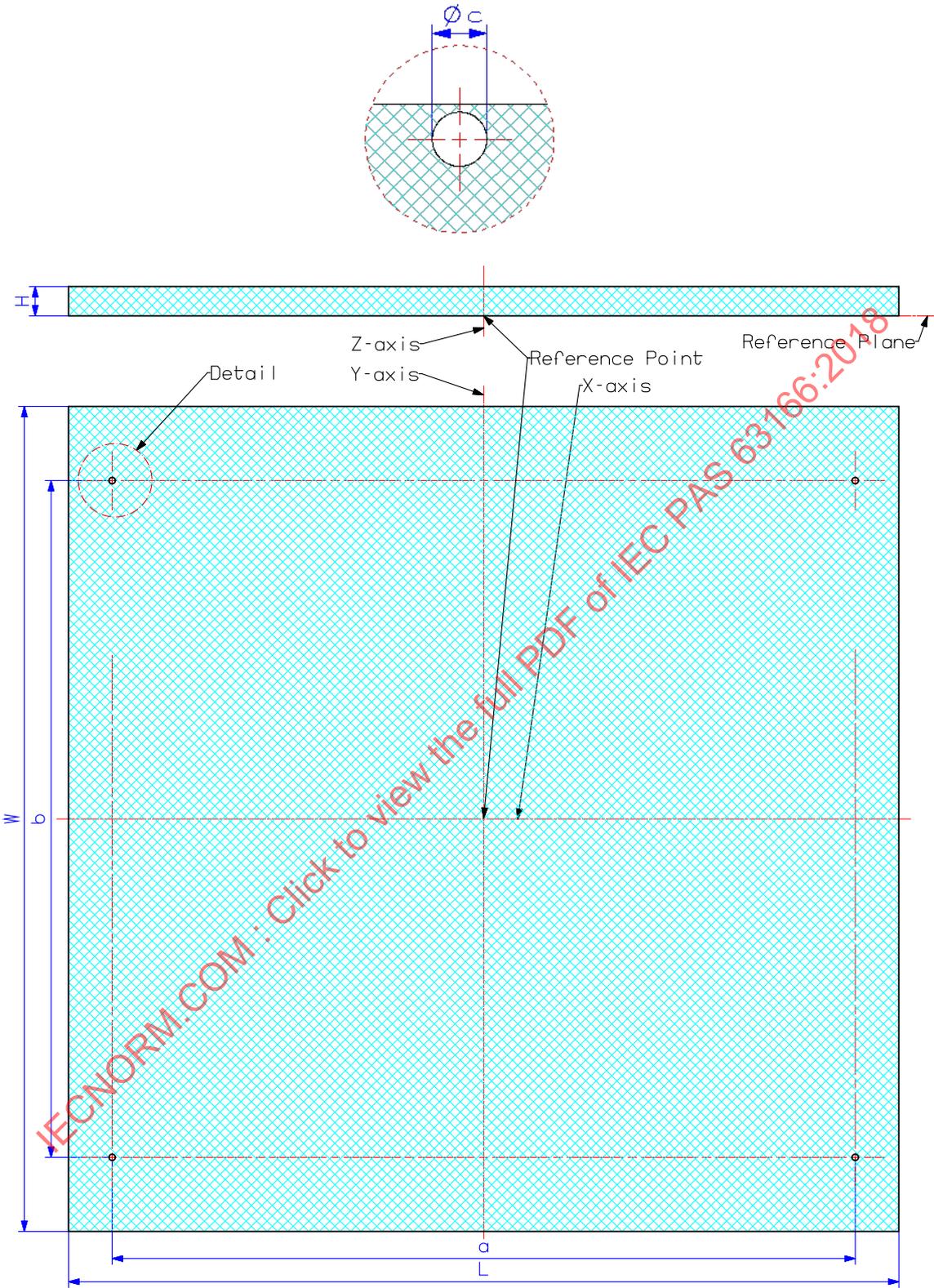


Figure 3-9: LED Module Demarcation of the L56W56 category.

The top figure shows the detail.

3.3.9 L56W2

The LED Module Demarcation¹⁰ of the L56W2 category is defined in Figure 3-10 and Table 3-9. The four mounting holes at the bottom of the diagram of Figure 3-4 are optional for the LED Module but mandatory for the Luminaire. The designation for this category is 'L56W2'.

dimension	Value
L	560
W	24
H	20
a	125
b	18,4
d	30
Øc	4,3

Table 3-9: LED Module Demarcation of the L56W2 category.

Notes to Figure 3-11:

- X-axis is symmetry axis for the outline and the cross-hair lines of the mounting holes.
- Y-axis is symmetry axis for the outline and mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

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¹⁰ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

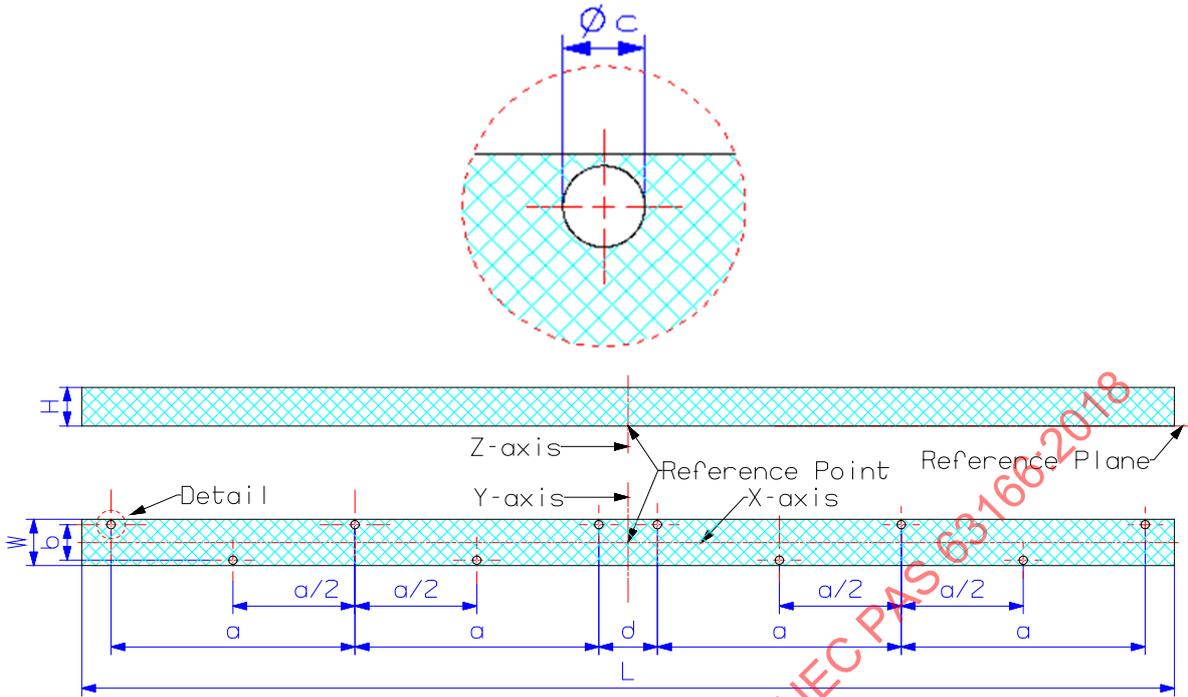


Figure 3-10: LED Module Demarcation of the L56W2 category.

The top figure shows the detail.

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3.3.10 L56W4

The LED Module Demarcation¹¹ of the L56W4 category is defined in Figure 3-11 and Table 3-10. The designation for this category is 'L56W4'.

dimension	Value
L	561
W	41
H	20
a	110
b	31
Øc	4,3
d	61

Table 3-10: LED Module Demarcation of the L56W4 category.

Notes to Figure 3-11:

- X-axis is symmetry axis for the outline and the cross-hair lines of the mounting holes.
- Y-axis is symmetry axis for the outline and mounting holes.
- The hashed area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

¹¹ In this demarcation model, the minimum diameter of the mounting holes at nominal position is specified. In typical designs the diameter of these holes will be larger allowing for a tolerance on the position of the holes.

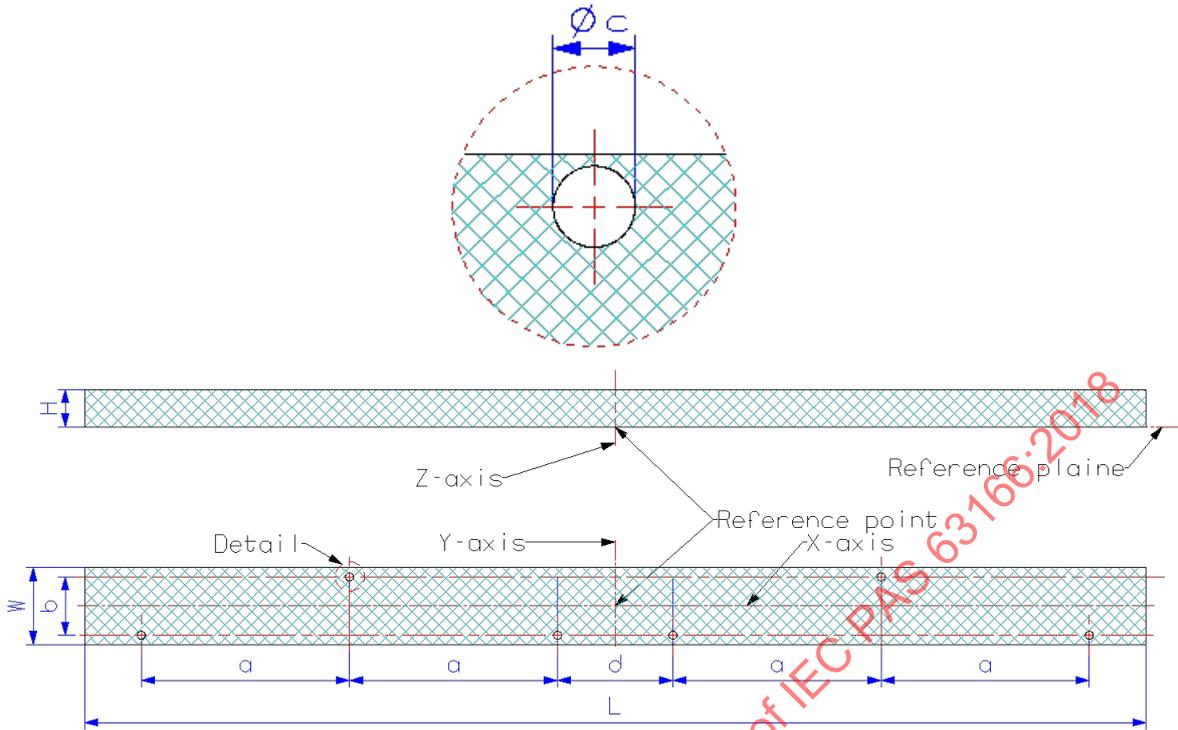


Figure 3-11: LED Module Demarcation of the L56W4 category.

The top figure shows the detail.

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3.4 Requirements on the mechanical interface of the Book-7 Luminaire

For each LED Module to be mounted in the Luminaire, the Luminaire shall be compliant with the LED Module demarcation for the corresponding category as defined in section 3.3.

3.4.1 Flatness and roughness of the Thermal Interface Surface

This Edition of Book 7 does not contain requirements on the flatness and roughness of the Thermal Interface Surface of the Luminaire.

3.4.2 Luminaire keep-out for interconnect

The Luminaire should foresee space for the interconnects between LED Module(s) and ECG and between ECG and external power.

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4 Photometric Interface

4.1 Light Emitting Surface

The Light Emitting Surface of the LED Module shall be such that there is no light emitted in the direction of the Reference Plane (see section 3.2). This edition of Book 7 does not contain further requirements on the Light Emitting Surface of the LED Module.

4.2 Operating conditions for measuring photometric parameters

For the purpose of this section, the provisions in [Book 1] - section 4.2 apply, with the following exceptions:

- The requirement on t_r does not apply.
- The heat sink(s) of the test fixture(s) shall maintain the temperature (t_p) within the range $t_{p, rated} \pm 1$ °C.

4.3 Luminous flux

For the purpose of this section, the provisions in [Book 1] - section 4.3 apply except for the flux categories in [Book 1], table 4-1. The allowed flux categories with corresponding minimum and maximum luminous flux values per luminous flux categories are defined in Table 4-1.

luminous flux category	Minimum luminous flux [lm]	Typical luminous flux [lm]	Maximum luminous flux [lm]
100	85	100	150
200	150	200	250
300	250	300	345
400	340	400	500
600	500	600	690
800	680	800	935
1100	935	1100	1275
1500	1275	1500	1725
2000	1700	2000	2300
2500	2125	2500	2875
3000	2550	3000	3450
4000	3400	4000	4600
5000	4250	5000	5750
6000	5100	6000	6900
7000	5950	7000	8050
8000	6800	8000	9200
10000	8500	10000	11500

Table 4-1: Luminous flux categories

4.4 Luminous intensity distribution

This edition of Book 7 does not contain requirements on the luminous intensity distribution of the LED Module.

4.5 Luminance uniformity

When designing Book-7 LED Modules with multiple LEDs, there is always a trade-off between low LED number and homogeneous fill factor of the module surface. Large LED numbers per area are associated with high luminance uniformity, meaning it is easy to construct a Luminaire where single LEDs are not visible as single bright spots.

In this section a method is described to measure and to evaluate the luminance uniformity of Book-7 LED Modules. This method is specifically designed to compare LED Modules in one idealized application, not to predict LED Modules appearance in any possible application. Rather, if a user has chosen a certain LED Module, he can use the data gathered with the methods described here to

estimate if another LED Module will result in similar, “higher” or “lower” luminance uniformity in his application.

Only a single LED Module is measured and assessed. Thus, the acquired data gives only indications about the luminance uniformity of one LED Module. The measurement setup for luminance uniformity is schematically depicted in Figure 4-1. The LED Module under test is placed on a mounting plate large enough to support the LED Module. On top of this, the Uniformity Test Diffuser (UTD) is placed. A luminance camera in sufficiently large distance to avoid image distortion is used to record the appearance of the UTD. A detailed description of the setup is in Annex B.

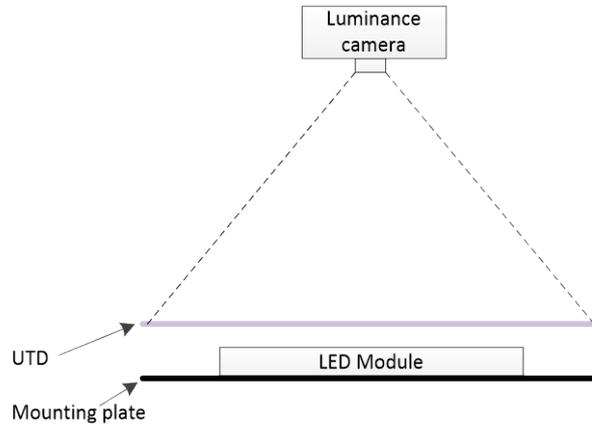


Figure 4-1: Set-up for luminance uniformity measurement.

The recorded luminance image shall be reduced in size to the luminance data area. The luminance data area is a rectangular area with dimensions equal to the dimensions of the Book-7 LED Module category of the LED Module under test. Note that the size of the luminance data area does not depend on the actual size of the LED Module under test. The LED Module shall be in the center of the luminance data area. The resulting image is normalized to its maximum value, leaving all pixel values between 0.0 (no luminance) and 1.0 (maximum luminance).

The data of the luminance data area shall be available in the LED Module Product Data Set as a greyscale image. This image shall be an 8-bit greyscale PNG image compliant with [ISO/IEC 15948] and with linear luminance value normalized between 0 (no luminance) and 255 (maximum luminance).

4.6 Correlated color temperature (CCT)

For the purpose of this section, the provisions in [Book 1] - section 4.6, apply.

4.7 Color rendering index (CRI)

For the purpose of this section, the provisions in [Book 1] - section 4.7, apply.

5 Electrical Interface

5.1 Electrical interface to the ECG

The LED Module defined in this Book 7 shall comply with the provisions of [LEDset-Pow].

The LED Module defined in this Book 7 shall comply with the provisions of [LEDset-Inf].

(Informative)

A LED Module that is compliant with [LEDset-Inf] can have either a 2-wire electrical interface (2 wires configured to be connected to a current source) or a 3-wire electrical interface (2 wires configured to be connected to a current source and the third wire is used to control the current of that current source). Moreover, such a LED Module may have additional wires and functionality as long as the LED Module can be used in the 2-wire or the 3 wire configuration as defined in [LEDset-Inf].

5.2 Electrical insulation

For the purpose of this section, the provisions in [Book 1] - section 5.1, apply.

It is recommended to specify the implemented electrical insulation according to the applicable standards in the Product Data Set of the LED Module.

5.3 Mechanical aspects of the electrical interface to the ECG

This edition Book 7 does not define the mechanical aspects of the electrical interface to the ECG.

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6 Thermal Interface

6.1 Background information (informative)

In general, one of the most challenging issues in LED lighting is related to the junction temperature of the LED. On the one hand this component is made of a semiconductor material and therefore it is sensitive to operating temperature, both in terms of performance and lifetime. On the other hand the operating temperature of the LED is not only determined by the design of the LED Module but also by the design of the Luminaire and by the ambient temperature.

For Book-7 LED Modules, the situation is special. Many Book-7 LED Modules are very tolerant with respect to the thermal interface. These LED Modules are more or less self-cooling. Even when the thermal interface is very poor, these modules do not overheat. On the other hand, some Book-7 LED Modules are more demanding with respect to the thermal interface. These LED Modules may overheat without special precautions.

6.2 General thermal requirements for Book-7 LED Modules

The LED Module manufacturer shall indicate in the Product Data Set the position of the temperature measurement point (typically on a hot spot near a LED or a solder point)¹². The temperature that is measured at this point is denoted: t_p .

The LED Module manufacturer shall list the value of the $t_{p, \text{rated}}$ in the Product Data Set and this value of $t_{p, \text{rated}}$ shall be such that if $t_p = t_{p, \text{rated}}$, a new sample of the LED Module (at zero burning hours) shows photometric values equal to the Rated values within tolerances defined in the Zhaga Interface Specification.

The LED Module manufacturer shall list the thermal headroom $t_{p, \text{headroom}}$ (see section 6.3) in the Product Data Set.

It is recommended to list in the PDS the value of the thermal power of the LED Module (P_{th}) as defined in [Book 1].

6.3 Thermal headroom of Book-7 LED Modules

In order to determine the thermal headroom of the LED Module, the LED Module is mounted in the Thermal Headroom Test Fixture which is defined in section 7.1.2. Following the test procedure as defined in section 8.3.1.3, the value of t_p is determined during normal operating conditions (among others at an ambient temperature of 25°C). This value is denoted: $t_{p, \text{normal}}$. The thermal headroom $t_{p, \text{headroom}}$ is derived from $t_{p, \text{rated}}$ and $t_{p, \text{normal}}$ using EQ. 6-1:

$$\text{EQ. 6-1:} \quad t_{p, \text{headroom}} = t_{p, \text{rated}} - t_{p, \text{normal}}$$

The value of the thermal headroom can be used by the Luminaire manufacturer to determine the measures that are required for thermal compatibility. LED Modules with $t_{p, \text{headroom}} \geq 20 \text{ }^\circ\text{C}$ are typically tolerant with respect to the thermal interface when applied in a typical Book-7 Luminaire. No extra tests of the thermal interface are required for this type of LED Modules.

LED Modules with $t_{p, \text{headroom}} < 20 \text{ }^\circ\text{C}$ are typically more demanding with respect to the thermal interface when applied in a typical Book-7 Luminaire. Without special precautions these LED Modules may overheat. LED Module manufacturers are recommended to include additional information in the PDS with respect to the thermal interface. And Luminaire manufacturers are advised to use this information and optionally perform additional tests to check thermal compatibility.

¹² This point is different from the measurement point of the Reference Temperature defined in book 1 as the position of t_p is LED Module dependent and typically does not lie on the Thermal Interface Surface.

Part 2: Compliance Tests

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7 Compliance test tools

7.1 LED Module test tools

7.1.1 Test Fixture PETF (photometric and electrical)

The PETF for Book 7 LED Modules is a temperature controlled heat sink that allows for mounting the LED-Module-under-test and that can be attached to the photometric measurement system.

7.1.2 Test Fixture THTF (Thermal Headroom)

Figure 7-1 illustrates the Thermal Headroom Test Fixture (THTF) used for thermal measurements of the LED Module. The Test Fixture consists of a metal frame (Figure 7-2), a metal back plate (Figure 7-3) and a cover plate (Figure 7-4).

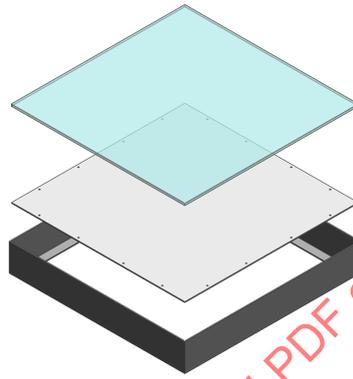


Figure 7-1 Thermal Headroom Test Fixture

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The mechanical dimensions of the frame of the Thermal Headroom Test Fixture are defined in Figure 7-2 and the requirements on the dimensions are listed in Table 7-1. The frame is made of steel.

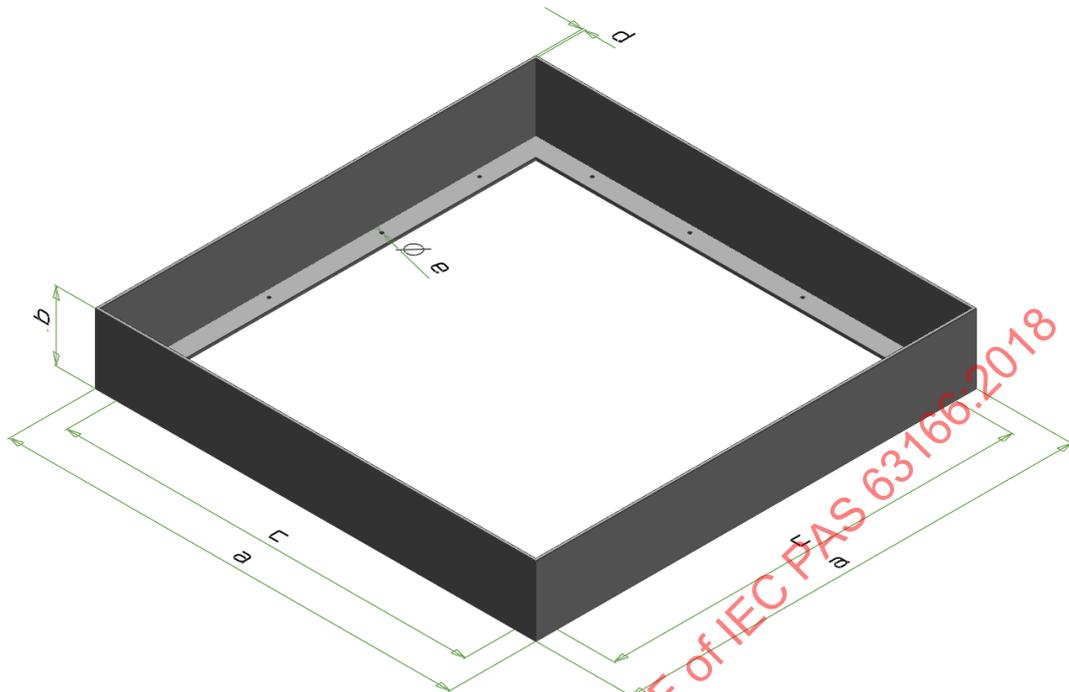


Figure 7-2 Mechanical dimensions of frame.

dimension	min	typical	max
a	580	581	582
b	89	90	91
c	528	530	532
d	0,6	0,7	0,8
e	3,3	3,4	3,5

Table 7-1 Mechanical dimensions of frame.

The mechanical dimensions of the back plate of the Thermal Headroom Test Fixture are defined in Figure 7-3 and the requirements on the dimensions are listed in Table 7-2. The back plate is made of stainless steel 1.4301 (X5CrNi18-10) with white coating and with a thermal conductivity of 15 W/mK +/- 3 W/mK.

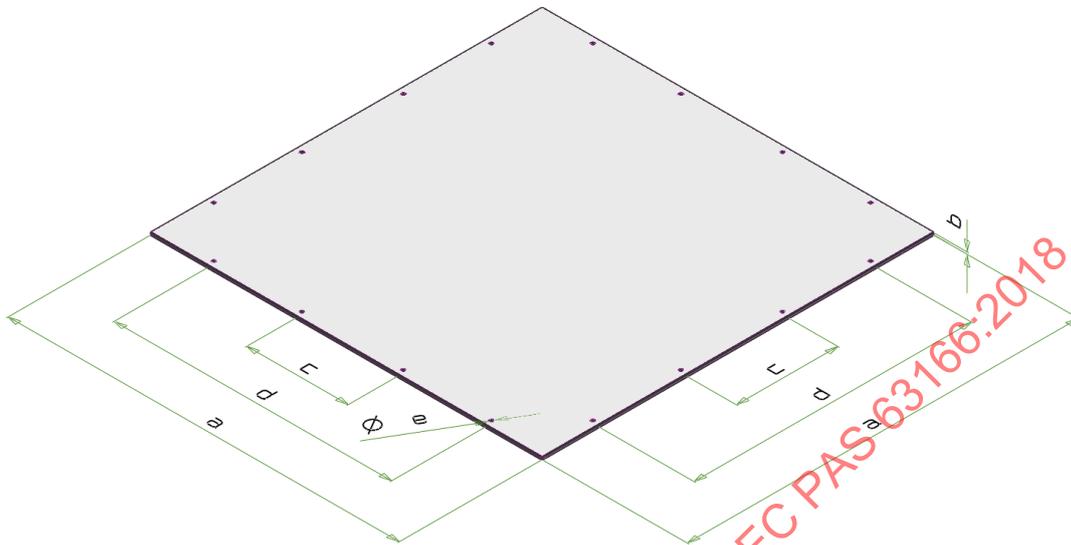


Figure 7-3 Mechanical dimensions of back plate.

dimension	min	typical	max
a	575,5	577	578,5
b	1,95	2,00	2,05
c	199,5	200	200,5
d	399,5	400	400,5
e	4,5	4,6	4,7
f	559,5	560	560,5

Table 7-2 Mechanical dimensions of back plate.

For mounting the LED Module, the back plate provides holes corresponding to the Book-7 LED Module category mechanical specification(s) in section 3 of this book. The position of the LED Module of the mounting plate shall be centered in both directions.

The mechanical dimensions of the cover plate of the Thermal Headroom Test Fixture are defined in Figure 7-4 and the requirements on the dimensions are listed in Table 7-3. The cover plate is made of transparent polycarbonate.

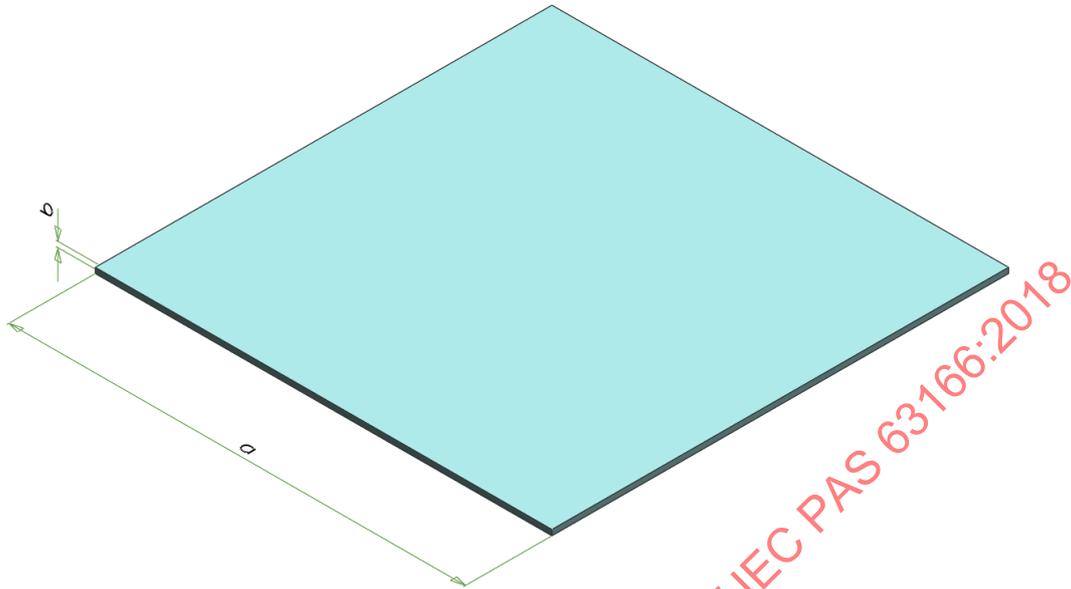


Figure 7-4 Mechanical dimensions of the cover plate.

dimension	min	typical	max
a	577	578	579
b	2,5	3	3,5

Table 7-3 Mechanical dimensions of the cover plate.

8 LED Module Compliance Tests

8.1 LED Module mechanical interface tests

8.1.1 Test of the mechanical interface of the LED Module

The purpose of this test is to verify the mechanical interface of the LED Module under test.

8.1.1.1 Test equipment

The mechanical interface should be tested with a (semi) automated 3D measuring equipment like a non-contact optical measuring system. The measurement accuracy shall be at least $\pm 0,05$ mm.

Alternatively, the mechanical interface may be tested with a gauge made of a material that ensures the accuracy mentioned below (for example 3 mm aluminum). In that case, it shall be verified that the gauge complies with the corresponding demarcation model. This verification shall be done with a (semi) automated 3D measuring equipment like a non-contact optical measuring system. The measurement accuracy shall be at least $\pm 0,05$ mm.

8.1.1.2 Test conditions

The mechanical interface shall be verified at 25 ± 5 °C.

8.1.1.3 Test procedure

- Determine the designation of the LED Module category from the Product Data Set of the LED Module under test.
- Find the corresponding LED Module Demarcation in section 3.3.
- Verify that the LED Module under test does not cross the corresponding LED Module Demarcation. Note that such verification includes the outline of the LED Module under test as well as the size, shape and position of the mounting holes within that outline. Additional guidelines for this test are provided in Annex C.

8.1.1.4 Pass criteria

The LED Module under test passes if the result of the LED Module Demarcation verification is positive. Using a (semi) automated 3D measuring equipment, verification of the LED Module Demarcation is positive if all measurement points are in the keep-in zone of the LED Module Demarcation with a tolerance of 0,05 mm. Using a gauge, verification of the LED Module Demarcation is positive if the module fits in the gauge.

8.2 LED Module photometric interface tests

8.2.1 Test of Luminous Flux

The purpose of this test is to verify the Rated luminous flux category of the LED Module under test.

8.2.1.1 Test equipment

For this test the Test Fixture PETF as defined in section 7.1.1 shall be used.

8.2.1.2 Test conditions

See section 4.2.

8.2.1.3 Test procedure

- Mount the LED Module-under-test on the PETF. The LES shall be tightly connected to the photometric measurement system.
- Connect a thermocouple to the t_p point of the LED Module at the position defined in the PDS of the LED Module and according to the instructions in the PDS of the LED Module. In case no instructions are provided, it is recommended to adhere to the instructions in annex K of [IEC 60598-1].

- Connect the LED Module to a power supply and turn on the power supply.
- Adjust the Ambient Temperature and the heat sink temperature(s) such that, after stabilization (see book 1; section A.1.3.4), all conditions defined in section 4.2 are met.
- Perform the test as described in [IES LM-79-08], Section 9.1.

8.2.1.4 Pass criteria

For the purpose of this section, the provisions in [Book 1] – section A.1.2.1.4, apply.

8.2.2 Test of correlated color temperature (CCT)

The purpose of this test is to verify the Rated CCT of the LED Module under test.

8.2.2.1 Test equipment

For this test the Test Fixture PETF as defined in section 7.1.1 shall be used.

8.2.2.2 Test conditions

See section 4.2.

8.2.2.3 Test procedure

Use the procedure in section 8.2.1.3 to measure the spectral power density (SPD) and calculate CCT according to [ANSI C78.377].

8.2.2.4 Pass criteria

For the purpose of this section, the provisions in [Book 1] – section A.1.2.3.4, apply.

8.2.3 Test of color rendering index (CRI)

The purpose of this test is to verify the Rated CRI of the LED Module under test.

8.2.3.1 Test equipment

For this test the Test Fixture PETF as defined in section 7.1.1 shall be used.

8.2.3.2 Test conditions

See section 4.2.

8.2.3.3 Test procedure

Use the procedure in section 8.2.1.3 to measure the spectral power density (SPD) and calculate the CRI simulating a color plate measurement according to [CIE 13.3].

8.2.3.4 Pass criteria

For the purpose of this section, the provisions in [Book 1] – section A.1.2.4.4, apply.

8.2.4 Test on luminance uniformity data

The purpose of this test is to verify the presence of graphical data representation of the luminance uniformity in the PDS of the LED Module under test.

8.2.4.1 Test equipment

None.

8.2.4.2 Test conditions

None.

8.2.4.3 Test procedure

- Check the presence in the PDS of a greyscale image according to the requirements in section 4.5.

8.2.4.4 Pass criteria

The LED Module under test passes if the greyscale image according to the requirements in section 4.5 is available in the PDS.

8.3 LED Module thermal interface tests

8.3.1 Test of thermal headroom of the LED Module

The purpose of this test is to verify the thermal headroom ($t_{p,headroom}$) of the LED Module under test.

8.3.1.1 Test equipment

For this test the Test Fixture PHTF as defined in section 7.1.2 shall be used.

8.3.1.2 Test conditions

- The Test Fixture shall be installed in a draught free room with the cover plate facing down and at a distance of at least 50 cm to the floor, to the ceiling and to the walls. The construction to support the Test Fixture shall be as open as possible. Preferably the Test Fixture is suspended.
- The Ambient Temperature shall be within the range 25 ± 5 °C and stable within the range ± 1 °C.
- The LED Module shall be connected to a power source according to the manufacturer's instructions. The input current and voltage shall be within 0,2% of the Rated values.
- The photometric output of the LED Module shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LED Module or the Test Fixture.

8.3.1.3 Test procedure

- Attach a thermocouple to the LED Module at the t_p -point specified in the PDS.
- Mount the LED Module in the Test Fixture according to the instructions in the PDS.
- Install the Test Fixture in a draught free and temperature controlled room.
- Turn on the LED Module and wait for stabilization of the temperature t_p (see book 1, section A.1.3.5).
- Measure the value of t_p and normalize it to an Ambient Temperature of 25 °C:

$$t_{p,normal} = t_p + 25 \text{ °C} - t_a$$
- Calculate $t_{p,headroom}$ according to EQ. 6-1.

8.3.1.4 Pass criteria

The LED Module under test passes if the calculated $t_{p,headroom}$ is not less than the Rated $t_{p,headroom} - 4$ °C.

8.4 LED Module electrical interface tests

All LED Module compliance tests as defined in [LEDset-Pow] shall be conducted and the LED-Module-under-test passes if all these tests pass.

All LED Module compliance tests as defined in [LEDset-Inf] shall be conducted and the LED-Module-under-test passes if all these tests pass.

8.5 LED Module Product Data Set test

For the purpose of this section, the provisions in [Book 1] – section A.1.6, apply.

9 Luminaire compliance tests

9.1 Luminaire mechanical interface tests

9.1.1 Test on the mechanical interface of the Luminaire for mounting the LED Module(s)

The purpose of this test is to verify the mechanical LED Module interface of the Luminaire under test.

9.1.1.1 Test equipment

The mechanical interface should be tested with a (semi) automated 3D measuring equipment like a non-contact optical measuring system. The measurement accuracy shall be at least +/- 0,05 mm.

Alternatively, the mechanical interface may be tested with a gauge made of a material that ensures the accuracy mentioned below (for example 3 mm aluminum). In that case, it shall be verified that the gauge complies with the corresponding demarcation model. This verification shall be done with a (semi) automated 3D measuring equipment like a non-contact optical measuring system. The measurement accuracy shall be at least +/- 0,05 mm.

9.1.1.2 Test conditions

The mechanical interface shall be verified at 25 ± 5 °C.

9.1.1.3 Test procedure

- Determine the designation of the LED Module category from the Product Data Set of the Luminaire under test. Note that if the Product Data Set of the Luminaire under test lists multiple LED Module categories, the next steps shall be repeated for each of the listed LED Module categories.
- Find the corresponding LED Module Demarcation in section 3.3.
- Verify that the Luminaire under test, including mounting means such as screws does not cross the corresponding LED Module Demarcation. Additional guidelines for this test are provided in Annex C.

9.1.1.4 Pass criteria

The Luminaire under test passes if the result of the LED Module Demarcation verification is positive for all LED Module positions in the Luminaire and for all LED Module categories listed in the PDS. Using a (semi) automated 3D measuring equipment, verification of the LED Module Demarcation is positive if all measurement points are in the keep-out zone of the LED Module Demarcation with a tolerance of 0,05 mm. Using a gauge, verification of the LED Module Demarcation is positive if the gauge fits in the LED module position in the Luminaire.

9.2 Luminaire Product Data Set test

For the purpose of this section, the provisions in [Book 1] – section A.2.6, apply.

Annexes

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Annex A Product Data Set requirements

In this section the requirements with respect to the Product Data Sets of Zhaga products defined in this Book 7 are listed.

A.1 LED Module Product Data Set

The LED Module Product Data Sets shall contain the following information:

- the Book-7 LED Module category designation
- Luminous flux category at $t_{p,rated}$
- CCT category at $t_{p,rated}$
- CRI at $t_{p,rated}$
- A greyscale image with a format as defined in section 4.5.
- the position of the temperature measurement point t_p
- the value of the $t_{p,rated}$
- the value of $t_{p,headroom}$

On top of the parameters listed above, the LED Module PDS shall also include those parameters related to the electrical interface that are mandated PDS items in [LEDset-Pow].

A.2 Luminaire Product Data Set

The Luminaire Product Data Sets shall contain the following information:

- The designation(s) of the Book-7 LED Module category that can be accommodated in the Luminaire. For each category, the Luminaire Product Data Set shall also show the number of modules that can be accommodated.

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Annex B Measurements on Luminance uniformity (informative)

In this annex, a detailed description is given of the measurement of luminance uniformity of book-7 LED Modules. LED Module manufacturers should use this information for generating the luminance uniformity related data in the PDS of the LED Module.

B.1 Test equipment

The measurement setup for this test is depicted in Figure B-1.

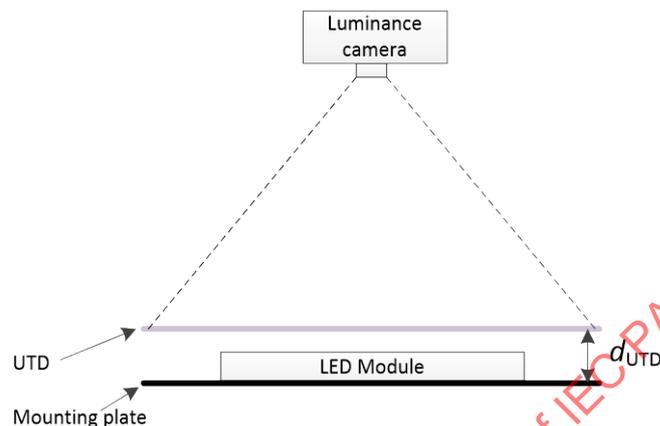


Figure B-1: Set-up for luminance uniformity measurement.

The LED Module under test is placed on a mounting plate large enough to support the LED Module. On top of the LED Module, the Uniformity Test Diffuser (UTD) is placed. This diffuser shall have similar optical properties as a 3mm thick translucent plastic sheet, with a scattering angle (FWHM) of 40° to 50° for normal incident light (for example Evonik DF23 7H)¹³. The UTD shall extend beyond the luminance data area (see section 4.5). The UTD shall be mounted at least a distance equal to d_{UTD} in every direction coplanar to the mounting plate.

The distance between mounting plate and UTD (d_{UTD}) shall be 20 mm (independent of the dimensions of the LED Module)¹⁴.

A luminance camera shall be placed at a distance to the UTD of at least 1 times the largest elongation of the luminance data area. A typical distance of at least 1,00 m is recommended. The optical axis of the luminance camera shall be aligned with the geometrical center of the module under test.

The luminance camera shall be aimed at the LED Module, and record local luminance with a resolution of at least 2 pixel per mm in each dimension (i.e. at least 4 pixels per mm² with square pixels).

B.2 Test conditions

- It is assumed that ambient conditions like temperature, humidity do not significantly affect the measurement result.
- The LED Module shall be mounted on the mounting plate according to the manufacturer's mounting instructions.
- The LED Module shall be connected to a power source according to the manufacturer's instructions. The input current and voltage shall be within 0,2% of the Rated values. The photometric output of the

¹³ This special test diffuser has been chosen to reduce peak luminance of the LEDs, similar as in a typical luminaire situation. The diffusing angle and back scattering are relatively low, to make the set up geometrically robust and minimize the effect of a reflective LED Module surface.

¹⁴ This rather low value (compared to a typical Book-7 luminaire, which has a distance of 50mm to 90mm) was deliberately chosen to get a better visible and better distinguishable outcome of the measurement.

LED Module shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LED Module.

B.3 Test procedure

- Mount the LED Module on the mounting plate and operate it according to the manufacturer's instructions.
- Place the UTD in the distance d_{UTD} from the mounting plate.
- Adjust the luminance camera such that
 - the optical axis is at center of LED Module
 - the luminance camera is focused onto the UTD
 - the luminance camera captures at least the luminance data area.
 - no pixels are overexposed
 - camera noise is minimal.
- Make a luminance image.
- Format the luminance image data.
 - Crop all data beyond the luminance data area.
 - Normalize the resulting image to its maximum value, leaving all pixel values between 0,0 (no luminance) and 1,0 (maximum luminance).
 - Depending on the luminance resolution of the luminance camera, the luminance values can be rounded. A minimum resolution of two significant digits is recommended.
 - Generate a greyscale image according to the requirements in section 4.5.

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Annex C Guidelines for mechanical interface test (informative)

The procedure for the compliance test on the mechanical interface of the LED Module or the Luminaire requires the verification that the LED Module or the Luminaire does not cross the corresponding LED Module Demarcation. Such verification can be performed using (semi-)automated 3D measuring equipment like a non-contact optical measuring system. This annex provides some guidelines on the number of measurement points and their positions to be used for such verification. The example in Figure C-1 will be used to provide these guidelines.

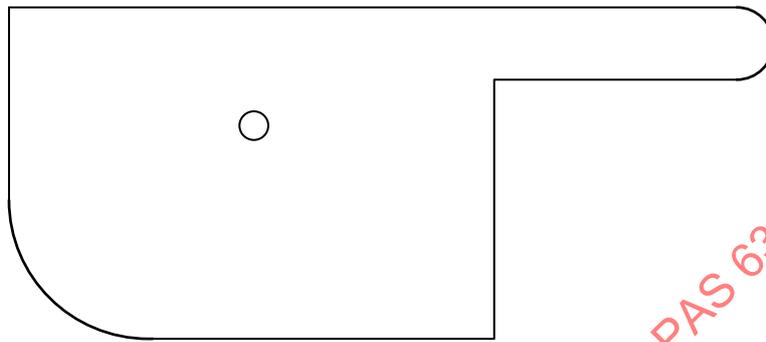


Figure C-1: Example of a LED Module.

As a first step, the outline of the LED Module (including mounting holes) is divided into segments with approximately equal curvature. In each section x , the minimum curvature in that section is denoted by r_x .

As a second step, measurement points are defined at the boundaries between sections. The result of these steps is shown in Figure C-2.

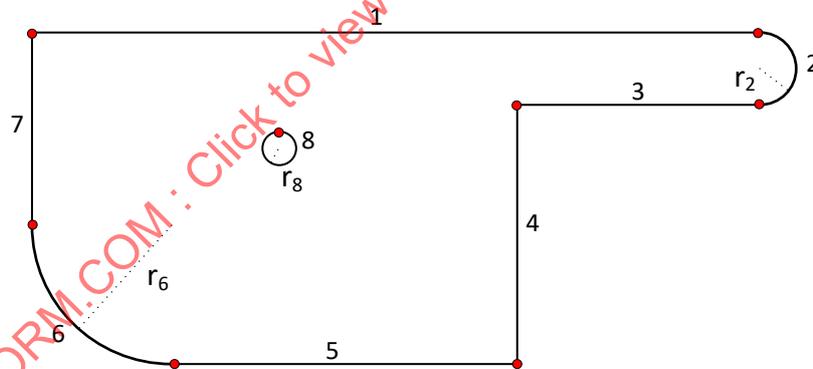


Figure C-2: Example of a LED Module with sections

As a third and final step, each section is divided in sub-sections with a maximum length d with the value of d fulfilling the following requirements:

- $d \leq \frac{r_x}{2}$ and
- $d \leq 10 \text{ mm}$

Additional measurement points are defined at the boundaries of these subsections. The result of these steps is shown in Figure C-3.

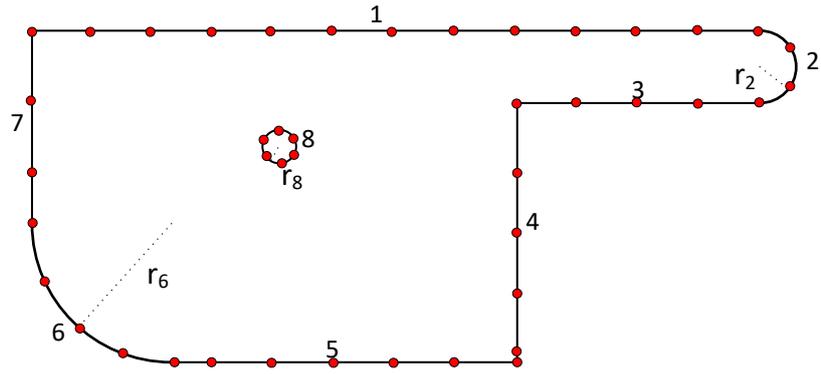


Figure C-3: Example of a LED Module with measurement points.

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Annex D History of Changes

Location	Change	Reason
Document	Update text to specify a LED Module rather than an LLE. <ul style="list-style-type: none"> • Add mandatory reference to MD-SIG power interface specification and MD-SIG information interface specification (section 5.1) • Add compliance tests related to the electrical interface • Remove specification of the control interface • Many editorial changes throughout the document. 	
3.2.2	Specification of new category L14W2	
Document	Align document with new template	

Table D-1: Changes from Edition 1.3 to Edition 1.4.

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Subdivision 2

Zhaga Interface Specification Book 1 Overview and Common Information

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1 General

1.1 Introduction

The Zhaga Consortium is a global organization that aims to standardize LED Light Engines and associated components. A LED Light Engine is a light source for general lighting that is based on solid state technology, and typically consists of one or more LEDs combined with an Electronic Control Gear. Examples of associated components are LED Modules, Electronic Control Gears, and Holders. Zhaga has created a set of interface specifications, known as Books defining interfaces between LED Light Engines, associated components and Luminaires.

Book 1 is a special Book in the sense that it provides common information, which is relevant to all other Books in the series. In addition, Book 1 defines requirements and compliance tests, which are applicable across multiple Zhaga books. Such Books refer to those requirements and compliance tests as applicable.

1.2 Scope

This Book 1 defines the common concepts that underlie the Zhaga interface specifications. In addition, this Book 1 specifies general requirements for Zhaga compliant LED Light Engines, associated components and Luminaires.

Each of the other Zhaga interface specifications details the requirements and the tests for particular types of Zhaga products. These Books are published separately for ease of revision and additional Books will be added as and when a need for them is recognized.

The objective of this Book 1 is to provide a set of requirements and compliance tests which are applicable to most Zhaga products and which can be called up as required by the other Books. Accordingly, the provisions of this Book 1 apply only in the specific contexts defined in the other Books. The other Books, in making reference to any of the sections in this Book 1, specify the extent to which that section is applicable. The other Books may also include additional requirements as necessary. All Zhaga Books are self-contained and therefore do not contain references to other Zhaga Books apart from this Book 1.

1.3 Conformance and references

1.3.1 Conformance

All provisions in the Zhaga interface specifications are mandatory, unless specifically indicated as recommended, optional or informative. Verbal expressions of provisions in the Zhaga interface specifications follow the rules provided in Annex H of ISO/IEC Directives, Part 2:2011. For all clarity, the word “shall” indicates a requirement that is to be followed strictly in order to conform to the Zhaga interface specifications, and from which no deviation is permitted. The word “should” indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited. The word “may” indicates a course of action permissible within the limits of the Zhaga interface specifications. The word “can” indicates a possibility or capability, whether material, physical or causal.

1.3.2 Normative references

[ANSI C78.377]	American National Standard for electric lamps—Specifications for the Chromaticity of Solid State Lighting Products, ANSI NEMA ANSLG C78.377
[CIE 13.3]	Method of measuring and specifying colour rendering properties of light sources, CIE 13.3
[IEC TR 61341:2010]	Method of measurement of centre beam intensity and beam angle(s) of reflector lamps
[IEC TR 62732]	Three-digit code for designation of colour rendering and correlated colour temperature
[IES LM-79-08]	IES Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products, IES LM-79-08

[NIST TN 1297]	NIST Technical Note 1297; 1994 Edition—Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results
[Zhaga-ECG]	Zhaga Interface Specification, Book 13 Separate Electronic Control Gear.

1.3.3 Informative references

[Zhaga LTLA]	Zhaga Logo Trademark License Agreement
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1.4 Common definitions¹⁵

Ambient Temperature	Average temperature of the air in the environment where the Luminaire (or Test Fixture) is applied. A few typical examples are: <ul style="list-style-type: none"> • In case of an outdoor Luminaire or a suspended indoor Luminaire, the Ambient Temperature is the temperature of the air in the vicinity of the Luminaire. • In case of a recessed Luminaire, the Ambient Temperature is the temperature of the air in the room, below the ceiling and in the vicinity of the Luminaire.
Authorized Testing Center	Organization that is authorized by the Zhaga consortium to perform certification tests for a specific Book.
Book	A Zhaga interface specification.
Built-in ECG	An ECG generally designed to be built into a luminaire, a box, an enclosure or the like and not intended to be mounted outside a luminaire, etcetera without special precautions.
Compatible	Two or more Zhaga products are Compatible if the combination can function as intended. Designation A code which identifies a Zhaga compliant product.
Electronic Control Gear	A unit that is located between the external power and one or more LED Modules to provide the LED Module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.
External Power	The electrical power that is supplied to the LED Light Engine. Typically this is the mains power, but it can also be from another source like a battery or an application specific power grid.
Holder	A component that maintains the LED Light Engine or the LED Module in a functional position, and establishes electrical contact with the LED Light Engine or the LED Module.
Independent ECG	An ECG consisting of one or more separate elements so designed that it can be mounted separately outside the luminaire, with protection according to the marking of the ECG and without any additional enclosure. This may consist of a Built-in ECG housed in a suitable enclosure which provides all the necessary protections according to its marking.
Integrated ECG	An ECG of a LLE that is accommodated in the same housing as the LED module(s) of the LLE. This combination is an Integrated LED Light Engine.
Integrated LED Light Engine	A LED Light Engine that consists of a single housing. This is the same as a “LED Light Engine with Integrated ECG”. Note that a module, complying with a specific Book that describes a LLE with Separate ECG but that is directly connected to external power would be an Integrated LLE and thus would be out of scope of that Book.

¹⁵ The definitions are possibly further restricted in the other Zhaga Books.

Interchangeable	Two Zhaga products are Interchangeable if replacement of the first product with the second product in a system results in comparable photometric and dimming properties of that system.
LED Light Engine	A combination of one Electronic Control Gear and one or more LED Modules and means for interconnecting these components. A LED Light Engine may consist of multiple housings.
LED Module	A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.
Light Emitting Surface	A surface of a LED Light Engine or LED Module with specific dimensions, position and orientation through which the light is emitted.
Luminaire	A lighting fixture which provides an appropriate environment for one or more LED Light Engines.
Luminaire Optics	Set of one or more optical elements, which shape the light output of the LLE, not being part of the LLE itself.
Measurement Uncertainty	Measurement Uncertainty is the same as “expanded uncertainty” as defined in [NIST TN 1297].
Optics Contact Area	Physical surface in the LLE or LED Module with a defined shape and position which allows for a stable and functional positioning of the Luminaire Optics on the LLE or LED Module.
Product Data Set	The combined data in the product data sheet, product label and product Designation. Rated <parameter> The value of the <parameter> as listed in the Product Data Set. Examples: the Rated voltage, the Rated frequency, etcetera.
Rated Operating Temperature	Value of the Reference Temperature (t_r) at which the Rated LLE or LED Module values are specified.
Reference Temperature	The temperature at a specified position on the Thermal Interface Surface under steady state operating conditions. The exact coordinates of this position are defined for each type of LLE or LED Module in the respective Book.
Relative Partial Luminous Flux	Percentage of the luminous flux that is emitted by a light source into the rotationally symmetric solid angle bounded by two polar angles (see also section 4.4).
Separate ECG	An ECG of an LLE that is accommodated in a housing that is separate from the LED module(s) of the LLE.
Test Engine	A device that is used to define and measure properties of a Luminaire.
Test Fixture	A device that is used to define and measure properties of a LED Light Engine or a LED Module.
Thermal Interface Material	Material at the Thermal Interface Surface which has the purpose to improve the heat transfer from the LLE or LED Module to the heat sink of the Luminaire.
Thermal Interface Surface	The surface of the LLE, LED Module or Thermal Test Engine that makes physical contact with the surface of the heat sink of the Luminaire.
Zhaga Consumer Product.	A Zhaga Consumer Product is intended to be applied and replaced by consumers.
Zhaga Professional Product	A Zhaga Professional Product is intended to be applied by a Luminaire maker.

1.5 Common acronyms

ATC	Authorized Testing Center
CCT	correlated color temperature
CRI	color rendering index
DUT	device-under-test
ECG	Electronic Control Gear
LED	light emitting diode
LES	Light Emitting Surface
LLE	LED Light Engine
NA	not applicable
OCA	Optics Contact Area
PETF	Photometric & electrical Test Fixture
PCB	printed circuit board
RMS	root mean square
TIM	Thermal Interface Material
TIS	Thermal Interface Surface
TPTF	thermal power Test Fixture
TTE	thermal Test Engine
TUTF	thermal uniformity Test Fixture

1.6 Common symbols

P_{el}	Electrical power consumed by the LLE (unit: W).
$P_{el,mod}$	Electrical power consumed by the LED Module (unit: W).
P_{vis}	Radiant flux of the LLE or LED module in the wavelength range from 380nm up to 780nm (unit: W).
P_{th}	Thermal power generated in the LLE or LED Module (unit: W).
$P_{th,rear}$	Thermal power that is drained from the LLE or LED Module through the Thermal Interface Surface (unit: W)
$P_{th,front}$	Thermal power that is drained from the LLE or LED Module by convection and IR radiation (unit: W)
R_{th}	Thermal resistance from the Thermal Interface Surface to the environment (unit: K/W).
$R_{th,max}$	Value of the thermal resistance from the Thermal Interface Surface to the environment for which holds: $t_r = t_{r,max}$ (unit: K/W).
$R_{sp}(i,j)$	Thermal spreading resistance between measurement points i and j (unit: K/W).
R_{sp}^{max}	Maximum thermal spreading resistance (unit: K/W).
$SPD(\lambda)$	Spectral Power Distribution (unit: W/nm). $SPD(\lambda)$ corresponds to what is expressed as “total spectral radiant flux” in [IES LM-79-08].
t_a	Ambient Temperature (unit: °C).
t_r	Reference Temperature (unit: °C).
$t_{r,max}$	Rated Operating Temperature (unit: °C).

1.7 Common conventions

1.7.1 Cross references

Unless indicated otherwise, cross references to sections in either this document or documents listed in section 1.3, refer to the referenced section as well as the sub sections contained therein.

1.7.2 Informative text

With the exception of sections that are marked as informative, informative text is set in italics.

1.7.3 Terms in capitals

All terms starting with a capital are defined in section 1.4.

1.7.4 Units of physical quantities

Physical quantities are expressed in units of the International System of Units.

1.7.5 Decimal separator

The decimal separator is a comma (“,”).

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2 Overview of Zhaga (informative)

2.1 About Zhaga

Zhaga has created a set of interface specifications, known as Books defining the interfaces between Zhaga products. A Zhaga product can be a LED Light Engine, an associated component or a Luminaire. Examples of associated components are LED Modules, Electronic Control Gears, and Holders. The Zhaga Consortium aims to facilitate easy exchange of LED Light Engines and associated components in a Luminaire. Replacement may be attractive because of superior characteristics of the new LLE or component featuring new technology or for second source choices for optimizing the logistic process or simply to be open for more cost effective alternatives. Another important use case is the replacement of a LLE or component by another one with (photometric) properties that better fit a new application. The replacement of LED Light Engines or associated components is facilitated by defining the following interfaces between LLEs, components and Luminaires:

- mechanical interface
- photometric interface
- electrical interface
- thermal interface
- control interface

The minimum requirements for the information in the Product Data Set are also defined in each Book. A Zhaga interface specification defines either a Zhaga Professional Product or Zhaga Consumer Product. A Zhaga Professional Product is intended to be applied by a Luminaire maker while a Zhaga Consumer Product is intended to be applied and replaced by consumers.

The Zhaga interface specifications do not define safety requirements (electrical, thermal etcetera) of Zhaga products. There is only a recommendation to specify in the Product Data Set of the LLE or LED Module the implemented electrical insulation.

Note that a type of LED Light Engine or LED Module which is defined in a Book may be further categorized in that Book, for example in categories having different dimensions, different external powers or different Optics Contact Areas.

2.2 Zhaga building blocks and interfaces

In this section, the definitions of Zhaga building blocks are elaborated in their context. Each Book defines interfaces between Zhaga products being LED Light Engines, associated components and Luminaires (see section 2.1).

In the context of the Zhaga interface specifications, a Luminaire is a lighting fixture which provides an appropriate environment for one or more LED Light Engines and associated components (see Figure 2-1 and Figure 2-2). A Luminaire typically (but not necessarily) is comprised of a heat sink to carry away the heat generated in the LLEs, optical devices to reshape the light beam of the LLEs, means to supply electrical power to the LLEs, and means to attach the Luminaire to a wall, ceiling, stand, etcetera.

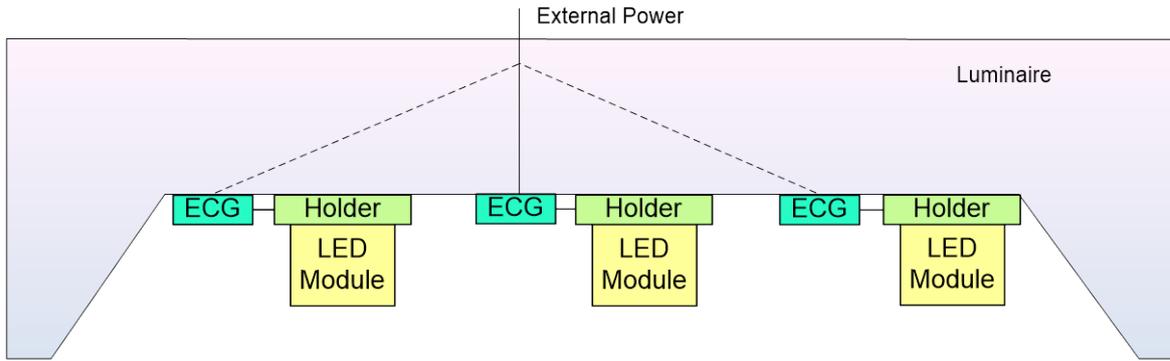


Figure 2-1: Schematic overview of a Luminaire and one or more non-integrated LED Light Engines

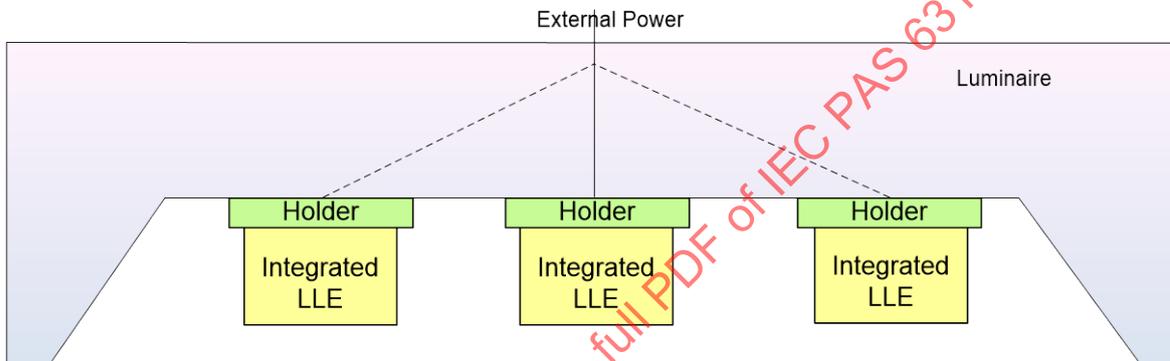


Figure 2-2: Schematic overview of a Luminaire and one or more integrated LED Light Engines

A LED Light Engine is defined as a combination of one Electronic Control Gear and one or more LED Modules (see Figure 2-3 and Figure 2-4).

A LED Module is defined as a light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its optical, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.

The Electronic Control Gear is defined as a unit that is located between the External Power and one or more LED Modules to provide the LED Module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

The LED Module(s) and the Electronic Control Gear can be in one housing as depicted in Figure 2-3. Such a system is denoted as a LED Light Engine with Integrated ECG, or alternatively as an Integrated LED Light Engine.

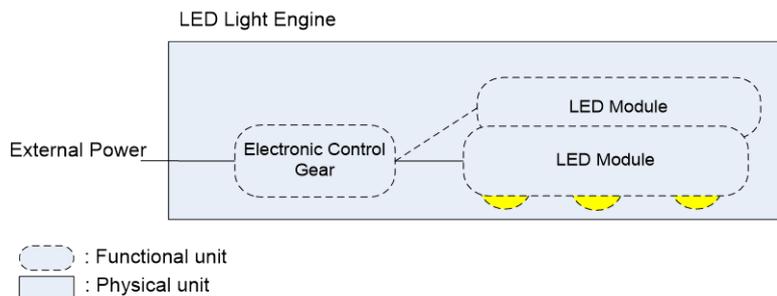
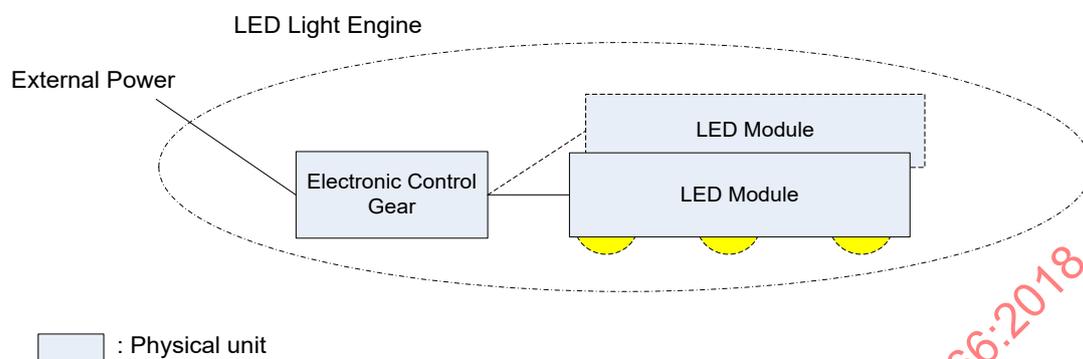


Figure 2-3: Schematic overview of a LED Light Engine with Integrated ECG

Alternatively, the LED Light Engine consists of an Electronic Control Gear and one or more LED Modules in separate housings as depicted in Figure 2-4. Such a system is denoted as a LED Light Engine with Separate ECG.

**Figure 2-4: Schematic overview of a LED Light Engine with Separate ECG**

2.3 Compatibility and Interchangeability

The Zhaga Consortium aims to define LED Light Engines and associated components which are Interchangeable in the sense that LED Light Engines or associated components, possibly designed by different manufacturers, can be interchanged without complications. Practically speaking this means that a professional lighting expert can replace one LLE or associated component by another one while maintaining essentially the same functionality. The Zhaga defines two concepts: Compatibility and Interchangeability that are relevant in this context.

Two Zhaga products are Compatible if the combination can function as intended. Two or more Zhaga products are Interchangeable if replacement of the first product with the second product in a system results in comparable photometric and dimming properties of that system.

Note that to ensure Interchangeability, the Luminaire also should be designed for Interchangeability. As an example, the Luminaire Optics should incorporate diffusing elements to account for different granularity of light emission by different LLEs or LED Modules.

2.4 Product Data Set

The Product Data Set is defined as the combined data in the product data sheet, product label and product Designation. The requirements with respect to the Product Data Set of a Zhaga product are defined in the applicable Book. These requirements guarantee that the Product Data Sets of Zhaga products contain the information which

- enables a check on Compatibility and
- enables a prediction of the (photometric) properties of a combination of Zhaga products.

2.5 Compliance testing

The basic principle of Zhaga is that, for example one manufacturer brings to the market a Zhaga certified product A while another manufacturer brings to the market a Zhaga certified product B. At a later point in time, a professional lighting expert may combine product A and product B in a Luminaire (product C) for a specific application.

One of the challenging issues is that the characteristics of the product A-B-C combination in terms of performance and lifetime depend on the characteristics of all three products and on how these three sets of characteristics match. In order to effectively cope with this situation, the Zhaga has defined procedures with tests to be conducted by manufacturers and Authorized Testing Centers and checks to be conducted by the one who intends to use these products. The checks are described in section 2.6 while the procedures with tests are described in sections 2.5.1 and 2.5.2.

2.5.1 Certification

Before market introduction of a Zhaga product, the following procedure with test is conducted. See also Figure 2-5. Next to measurements and tests that may be required for internal purposes and regulations, the manufacturer of a Zhaga product performs all measurements that are needed to generate the Product Data Set that is required by the Zhaga interface specification. The measurements are performed as defined in the Zhaga interface specification. The outcome of these tests is laid out in the Product Data Set that is provided with the product.

- The manufacturer sends the product (or product family) with associated Product Data Set to an Authorized Testing Center. The ATC performs all tests that are listed in the corresponding Zhaga Book and returns a test report and a test report summary to the manufacturer.
- The manufacturer sends the test report summary to the Zhaga Logo License Administrator. If the test report summary indicates that the product has passed all tests, the Zhaga Logo License Administrator certifies the product.

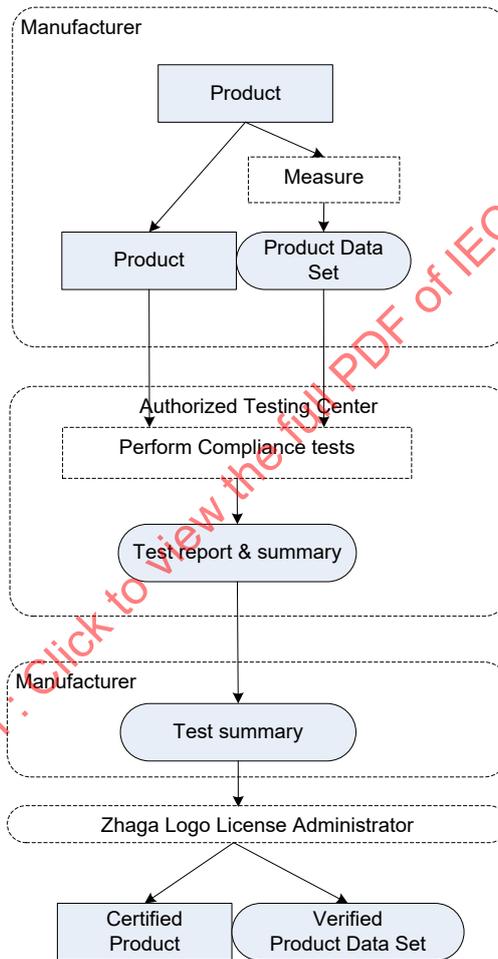


Figure 2-5: Overview of test and certification of Zhaga products

2.5.2 Market surveillance

After market introduction of a Zhaga product, a market surveillance procedure may be initiated to check for the compliance of the product. For details on the market surveillance procedure and consequences of non-compliance see [Zhaga LTLA].

2.6 Compatibility check

Using the Product Data Set of the Zhaga certified products, the Luminaire maker or, for some LLEs the end-user, can check whether two or more Zhaga products are Compatible.

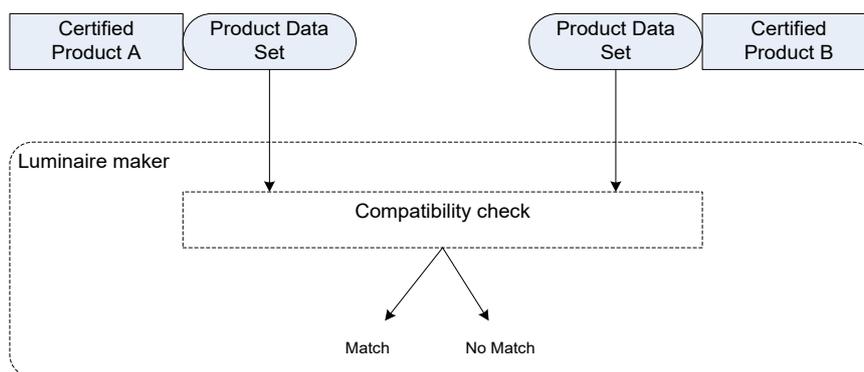


Figure 2-6: Compatibility check

2.7 Zhaga product certification

The Zhaga Consortium prohibits use of its trademark on products and on product documentation without a trademark license. Members can obtain a conditional trademark license by signing the so-called Zhaga Logo Trademark License Agreement [LTLA]. This agreement licenses the Zhaga Logo for use on products that have been tested and certified to be compliant with the Zhaga interface specification.

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3 Mechanical interface

3.1 Drawing principles

Unless indicated otherwise, the characteristics of the mechanical interface are specified according to the following principles:

- The dimensions are in millimeters.
- The minimum and maximum values provided in tables that accompany the drawings represent absolute limits, without any implied tolerance (neither positive, nor negative).
- Typical values as well as values between parentheses are informative.

3.2 Mechanical interface between Separate ECG and Luminaire.

The mechanical interface between the Separate ECG and the Luminaire is defined in [Zhaga-ECG].

3.3 Thermal expansion

The mechanical dimensions are verified at a temperature in the range 25 ± 5 °C. This is the temperature at which an LLE or LED Module is typically mounted in a Luminaire. Manufacturers should take all necessary measures to ensure that thermal expansion or contraction is accommodated for the complete operating temperature range.

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4 Photometric interface

4.1 Light Emitting Surface

A Light Emitting Surface (LES) is a surface associated to a LED Light Engine or a LED Module with specific dimensions, position and orientation through which the light is emitted and that has the following characteristics:

- All substantial light generated by the LED Light Engine or the LED Module is emitted through this surface.
- The center of the Light Emitting Surface coincides with the reference point of the luminous intensity distribution (See Figure 4-1).
- The LES is generally described by simple a geometrical shape, e.g. a circle or a rectangle. It has a physical boundary or is a virtual surface in the surrounding area of the LLE or the LED Module.

(Informative)

For each type of LLE or LED Module the definition of the LES may be further restricted in the respective Book according to the following principles:

- *When seen along the reference Z-axis, all parts of the light emitting area (LEDs, diffuse cover and/or mixing chamber) are covered by the LES.*
- *The position of the LES is chosen in a way, that all light emitting parts are behind the LES, when seen along the reference Z-axis.*
- *Inside a circular shaped LES, the LEDs may be placed in any arrangement, for example in a rectangular arrangement.*
- *A clear dome or cover above one or more LEDs is allowed to exceed the LES height.*

Examples LES definitions:

- *The LES is the domed cover of a multichip, phosphor covered LLE or LED Module.*
- *The LES is a circle or a rectangle which is large enough to encompass all silicone domes of packaged LEDs in the LLE or LED Module completely.*
- *In case the LEDs are encircled by the nearly vertical walls of a light guiding, mixing or diffusing element, the LES is described by the opening of this element.*
- *In the case of a diffuse cover covering the LEDs, the LES is described by the light emitting area of the diffuse cover.*

For each type of LLE or LED Module the requirements for the LES are defined in the respective Book.

4.1.1 LES categories

The Zhaga interface specifications define circular LES categories as listed in Table 4-1.

LES category designation	Minimum LES diameter ¹⁶	Maximum LES diameter
LES6.3	4,5	6,3
LES9	6,3	9,0
LES13.5	9,0	13,5
LES19	13,5	19,0
LES23	19,0	23,0
LES30	23,0	30,0
LES40	30,0	40,0

Table 4-1: Definition of circular LES categories

4.2 Operating conditions for measuring photometric parameters

In general, the characteristics of the light generated by a LED Light Engine or a LED Module depend on the operating conditions. This section defines the operating conditions that shall be applied when measuring the photometric parameters defined in this chapter.

In case the device-under-test is a LED Module the operating conditions for photometric tests shall be as follows:

- The LED Module shall be mounted in Test Fixture PETF according to the LED Module manufacturer’s mounting instructions.
- The LED Module shall be connected to a power source according to the manufacturer’s instructions. The input current and voltage shall be within 0,2% of the Rated values.
- The ambient temperature shall be stable within the range $25 \pm 1^\circ\text{C}$.
- The heat sink of the test fixture shall maintain the Reference Temperature (t_r) within the range $t_{r,max} \pm 1^\circ\text{C}$
- The photometric output of the LED Module shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LED Module and the Test Fixture.

In case the device-under-test is a LED Light Engine the operating conditions for photometric tests shall be as follows:

- The LLE or LED Module(s) in case of an LLE with Separate ECG shall be mounted in Test Fixture(s) according to the LLE manufacturer’s mounting instructions.
- The voltage and frequency of the External Power of the LLE shall be within 0,2% of the Rated values.
- The ambient temperature shall be stable within the range $25 \pm 1^\circ\text{C}$.
- The heat sink(s) of the test fixture(s) shall maintain the Reference Temperature (t_r) within the range $t_{r,max} \pm 1^\circ\text{C}$
- The photometric output of the LLE shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LLE and the Test Fixture(s).
- In case of an LLE with Separate ECG, the ECG should be mounted at a distance from the LED Module such that the ECG does not influence the results of the measurement.
- In case of an LLE with Separate ECG, the LED Module(s) shall be electrically connected to the ECG according to the LLE manufacturer’s instructions.
- In case the LLE features adjustable settings (for example output current of the ECG or de-rating settings), these settings shall be according to the manufacturer’s instructions.
- In case of an LLE with Separate ECG and more than one LED Module, photometric properties shall be measured on one LED Module, while the other LED Modules are also operated according to the manufacturer’s instructions to enable equal photometric output. If no instructions are provided, the

¹⁶ The range of LES diameter values for a specific LES category is excluding the lower bound and including the upper bound. For example, A LES with a diameter of 9,0 mm shall have a designation LES-9.

other LED Modules shall be operated in environmental conditions equal to the conditions of the LED-Module-under-test. The measurement setup should be such that the light output of the other LED Modules has no effect on the measurement result.

4.3 Luminous flux

The Zhaga interface specifications define luminous flux categories as listed in Table 4-2. In case of an LLE with multiple LED Modules, luminous flux is defined per LED Module.

luminous flux category	Minimum luminous flux [lm]	Typical luminous flux [lm]	Maximum luminous flux [lm]
100	90	100	150
150	135	150	250
250	225	250	350
350	315	350	500
500	450	500	800
800	720	800	1000
1000	900	1000	1500
1500	1350	1500	2000
2000	1800	2000	3000
3000	2700	3000	4000
4000	3600	4000	5000
5000	4500	5000	6000
6000	5400	6000	8000
8000	7200	8000	10000
10000	9000	10000	15000
15000	13500	15000	20000
20000	18000	20000	30000
30000	27000	30000	40000
40000	36000	40000	60000
60000	54000	60000	80000
80000	72000	80000	100000

Table 4-2: Definition of luminous flux categories

4.4 Luminous intensity distribution

For each type of LLE or LED Module, the required luminous intensity distribution may be defined in the respective Book. In case of a LLE with multiple LED Modules, the luminous intensity distribution is defined per LED Module.

The luminous intensity distribution may be defined in terms of Relative Partial Luminous Fluxes. The Relative Partial Luminous Flux is the percentage of the total luminous flux emitted into the rotationally symmetric solid angle bounded by the polar angles γ_1 and γ_2 , as shown in Figure 4-1.

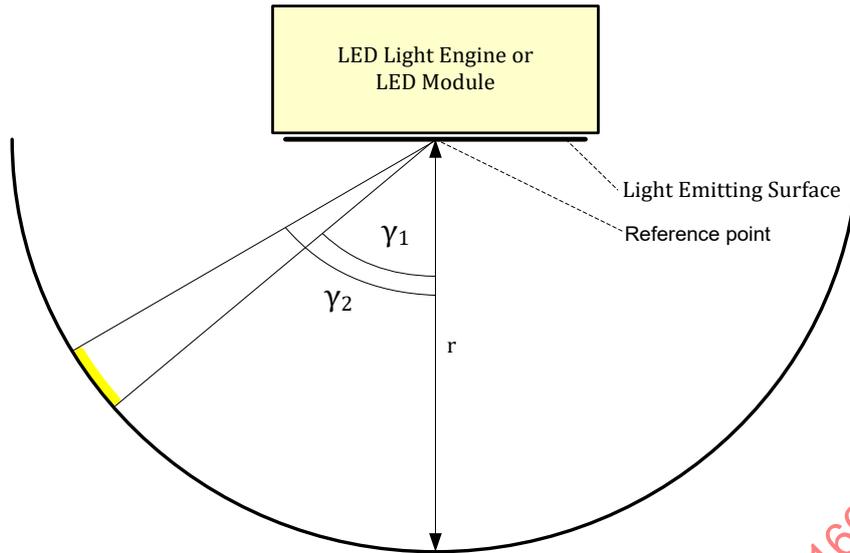


Figure 4-1: Rotationally symmetric solid angle bounded by the polar angles γ_1 and γ_2 which is used to define the Relative Partial Luminous Flux

4.4.1 Beam angle and beam angle categories

The beam angle shall be defined as in [IEC TR 61341:2010] and the beam angle categories shall be defined as in Table 4-3.

Beam angle category	Minimum beam angle (°)	Maximum beam angle (°)
6	3	9
12	9	15
17,5	15	21
25	21	29
35	29	41
55	41	70
90	70	110
120	110	150

Table 4-3: Definition of beam angle categories.

4.5 Luminance uniformity

For each type of LLE or LED Module, the required luminance characteristics may be defined in the respective Book. In case of a LLE with multiple LED Modules, luminance characteristics are defined per LED Module.

4.6 Correlated color temperature (CCT)

The CCT category of an LLE or LED Module shall comply with the provisions of [ANSI C78.377], with the exception that the target color points may be chosen freely within the quadrangles defined therein. Only the nominal CCT categories as specified in [ANSI C78.377] shall be used. The value, in combination with the CRI value shall be expressed using the three-digit code as defined in [IEC TR 62732]. In case of an LLE with multiple LED Modules, CCT is defined per LED Module.

4.7 Color rendering index (CRI)

The CRI value of the LLE or LED Module is defined in [CIE 13.3]. The value, in combination with the CTT value shall be expressed using the three-digit code as defined in [IEC TR 62732]. In case of an LLE with multiple LED Modules, CRI is defined per LED Module.

4.8 Luminaire Optics (informative)

The Luminaire Optics (e.g. reflectors, refractors or diffusers) are not defined in the Zhaga interface specifications. It is recommended to design Luminaire Optics in such a way, that the nominal parameter values of the LES and luminous intensity distribution result in the desired photometric characteristics of the LLE-Luminaire Optics combination.

Note: Due to the compound nature of many LED Module solutions, it is expected that Luminaire Optics designed for Zhaga compliant LLEs takes into account the structure of LED clusters, e.g. by using frosted surfaces or faceted structures to achieve comparable light output with all kinds of module technologies enabled by the Zhaga interface specifications. The luminance uniformity of the LED Module can provide information on the measures that need to be taken to achieve proper light distributed with Luminaire Optics. The larger the uniformity the more simple the measures are that need to be taken for a proper light distribution.

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5 Electrical interface

5.1 Electrical insulation (informative)

International and national regulations require that products on the market have to be compliant with product safety standards (for example UL standards in the USA, EN standards in Europe and JIS-Standard and PSE-Law in Japan) and individual manufacturers are responsible for this.

The electrical insulation of a complete LLE-Luminaire system is a safety item and depends on the electrical insulation implemented in the LLE, in associated components and in the Luminaire. Like all other safety requirements, electrical insulation is explicitly out of scope of the Zhaga interface specifications and it is the sole responsibility of the manufacturer that brings the product to the market.

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6 Thermal interface

6.1 Background information (informative)

One of the most challenging issues in LED lighting is related to the temperature of the LED. On the one hand this component is made of a semiconductor material and therefore it is sensitive to operating temperature, both in terms of performance and lifetime. On the other hand the operating temperature of the LED is not only determined by the design of the LLE or the LED Module but also by the design of the Luminaire. Manufacturers of Zhaga LLEs or LED Modules have no knowledge in which Luminaire the LLE or LED Module will be used. In order to effectively cope with this situation, a model of LLE-Luminaire or LED Module-Luminaire combination with respect to thermal behavior is defined in this section. This thermal interface model allows prediction of the Reference Temperature of a specific LLE - Luminaire combination or LED Module – Luminaire combination.

6.2 Generic thermal interface model

6.2.1 General case

In the thermal interface model, the light generating (and heat generating) component can be any one of the following devices:

1. A LLE with Integrated ECG. In this case the thermal interface is defined as the contact surface of the LLE and the Luminaire.
2. A LED Module. In this case the thermal interface is defined as the contact surface of the LED Module and the Luminaire.
3. A LLE with Separate ECG. In this case the thermal interface is defined as the contact surface of the LED Module and the heat sink the Luminaire and it is assumed that the ECG does not influence the thermal behavior of the Luminaire – LLE combination (See also section 6.1.12). In case of an LLE with multiple LED Modules, each LED Module has its thermal interface with the Luminaire.

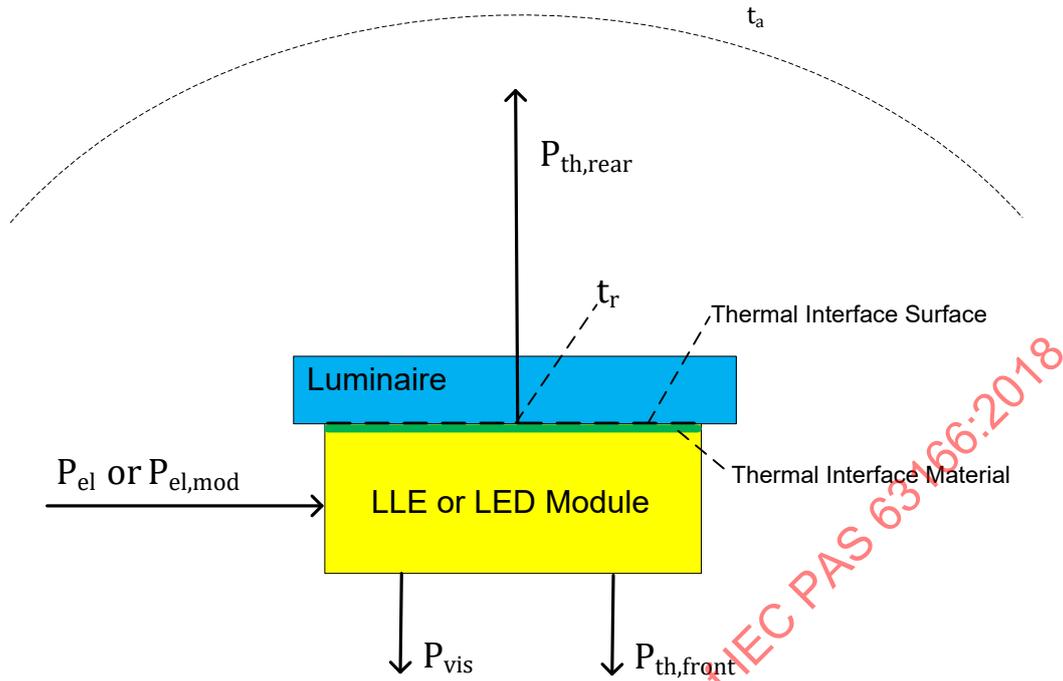


Figure 6-1: Thermal model of a LLE - Luminaire or a LED Module – Luminaire combination

Figure 6-1 illustrates the model of the thermal interface between the LLE or LED Module and the Luminaire. The LLE or LED Module consumes an amount of electrical power P_{el} and $P_{el,mod}$ respectively. This power is converted into visible light and heat:

EQ. 6-1:
$$P_{el} = P_{vis} + P_{th} \quad \text{or}$$

EQ. 6-2:
$$P_{el,mod} = P_{vis} + P_{th}$$

Here, P_{vis} is defined as the radiant flux in the visible light spectrum ($380 \text{ nm} < \lambda < 780 \text{ nm}$)¹⁷.

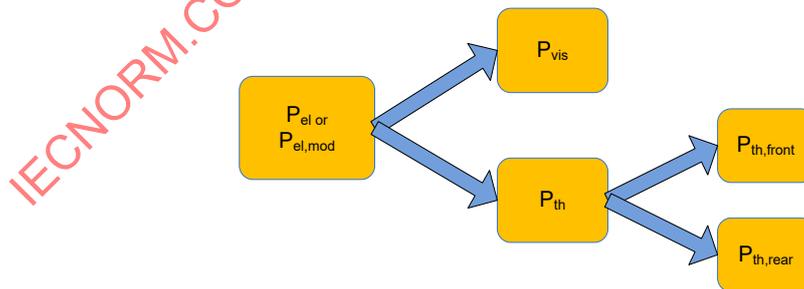


Figure 6-2: Power conversion

Some of the thermal power P_{th} is drained by convection and infra-red radiation. The sum of the thermal power drained by convection and IR radiation is denoted by $P_{th,front}$ ¹⁸. Typically a substantial

¹⁷ IR radiation is not included in P_{vis} and it is assumed that radiation in the range $\lambda < 380 \text{ nm}$ is negligible.

¹⁸ $P_{th,front}$ is defined to be the thermal power that is drained by convection and IR radiation to the environment and not re-absorbed by the LLE, the LED Module or the heat sink.

part of the thermal power will be drained through the Thermal Interface Surface to the heat sink of the Luminaire¹⁹. This portion is denoted by $P_{th, rear}$.

$$\text{EQ. 6-3:} \quad P_{th} = P_{th, rear} + P_{th, front}$$

The Thermal Interface Surface is defined as the surface of the LLE or LED Module that makes physical contact with the surface of the heat sink of the Luminaire. The Reference Temperature t_r is defined as the temperature at a specified position on the Thermal Interface Surface under steady state operating conditions²⁰. The exact position of this temperature point is defined for each type of LLE or LED Module in the respective Book.

The Zhaga defines the Rated Operating Temperature ($t_{r, max}$) and the value of $t_{r, max}$ shall be such that if $t_r = t_{r, max}$, a sample of the LLE or LED Module at zero burning hours shows photometric values equal to the Rated values within tolerances defined in the compliance test specifications of the Zhaga interface specifications.

The Reference Temperature t_r depends on the Ambient Temperature (t_a), the thermal resistance of the heat sink of the Luminaire (R_{th}) and the thermal power that is transferred through the Thermal Interface Surface ($P_{th, rear}$). Using a simple 1-dimensional model, the following relation is obtained:

$$\text{EQ. 6-4:} \quad t_r = t_a + R_{th} \cdot P_{th, rear}$$

For performance equal to or better than the Rated values, the LLE or LED Module should be operated under the condition

$$t_r \leq t_{r, max} \quad \text{Or:}$$

$$\text{EQ. 6-5:} \quad R_{th} \leq R_{th, max} \quad \text{with} \quad R_{th, max} = \frac{t_{r, max} - t_a}{P_{th, rear}}$$

6.2.2 Test Fixture TPTF

The relation between the thermal power drained by convection and IR radiation ($P_{th, front}$) on the one hand and the thermal power drained via the heat sink ($P_{th, rear}$) on the other hand depends on the geometry of the LLE-Luminaire system or the LED Module-Luminaire system. For each type of LLE or LED Module a Test Fixture TPTF may be defined in the respective Book. This Test Fixture TPTF shall be used to measure $P_{th, rear}$.

6.2.3 Rated Operating Temperature and safety (informative)

The Rated Operating Temperature ($t_{r, max}$) is used to define the conditions for the measurement of the temperature dependent parameters of the LED Light Engine or LED Module. In practical applications the Reference Temperature may be higher or lower than the Rated Operating Temperature. Also, the Rated Operating Temperature is not the absolute maximum Reference Temperature related to safety. In order to comply with safety regulations, the LLE manufacturer has to make sure that the LLE or LED Module operates safely under normal operating conditions. However, this is not mandated by Zhaga and will not be verified by the ATC. In typical products, the maximum Reference Temperature related to safety will be considerably higher than the Rated Operating Temperature ($t_{r, max}$). This maximum Reference Temperature related to safety may be listed in the Product Data Set of the LLE or the LED Module. Alternatively the LLE or LED Module manufacturer may specify the maximum thermal resistance related to safety in the Product Data Set.

6.2.4 Thermal overload protected LED Light Engine (Informative)

The Reference Temperature in a specific LLE-Luminaire or LED Module – Luminaire combination depends on many characteristics of the LLE or the LED Module, the Luminaire and the mounting (for example the TIM and the contact pressure). Zhaga does not mandate a protection in the LLE or LED Module that guarantees the Reference Temperature not to exceed an upper limit (for example by reducing power or shut down).

¹⁹ Heat transfer via conduction through other parts of the system is assumed to be negligible.

²⁰ "steady state" is defined in section A.1.3.4.

6.2.5 Ambient Temperature

As indicated in EQ. 6-5, the maximum thermal resistance of the LLE or LED Module ($R_{th,max}$) depends on the Ambient Temperature. With increasing Ambient Temperature $R_{th,max}$ decreases. This effect can be significant and shall be taken into account in the thermal compatibility check (section 6.2.7).

The LLE or LED Module manufacturer may list values of $R_{th,max}$ for several values of the Ambient Temperature. For each type of LLE or LED Module, Product Data Set requirements with respect to $R_{th,max}$ are defined in the respective Book. In case the Ambient Temperature is not listed in the Product Data Set, a value of 25 °C shall be used.

For each type of LLE or LED Module it is defined in the respective Book whether the Ambient Temperature shall be listed on the Luminaire Product Data Set or not.

In case the Ambient Temperature is listed in the Product Data Set of the Luminaire this value shall be used in the thermal compatibility check (section 6.2.7) to determine the corresponding $R_{th,max}$ of the LLE or the LED Module.

In case the Ambient Temperature is not listed in the Product Data Set of the Luminaire an independent judgment of the Ambient Temperature shall be made by the non-professional end-user or professional lighting expert and this value shall be used in the thermal compatibility check (section 6.2.7) to determine the corresponding $R_{th,max}$ of the LLE or LED Module.

6.2.6 Luminaires with multiple LLEs or multiple LED Modules

Within Zhaga a Luminaire is a lighting fixture which provides an appropriate environment for one or more LED Light Engines. Each LED Light Engine is a combination of one Electronic Control Gear and one or more LED Modules. In this section two cases for Luminaires with multiple LLEs or Multiple LED Modules are described.

6.2.6.1 Separate heat sinks

In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on separate heat sinks, it is assumed that the LLEs or LED Modules do not influence each other from a thermal point of view. The general model described in section 6.2.1 can be applied to each LLE or LED Module individually.

6.2.6.2 One heat sink

In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on a single heat sink, all LLEs or LED Modules shall be identical²¹. For such systems, the thermal resistance of the Luminaire is defined as:

$$\text{EQ. 6-6:} \quad R_{th} = \frac{MAX(t_{r,i}) - t_a}{P_{th,rear}}$$

with $t_{r,i}$: Reference Temperature of a LLE_i or LED Module_i
 $P_{th,rear}$: Thermal power per LLE or LED Module

6.2.7 Thermal compatibility check

In general, the thermal resistance of a heat sink depends on the thermal power applied to the Thermal Interface Surface ($P_{th,rear}$). For that reason several values of $P_{th,rear}$ and corresponding values of R_{th} are listed on the Product Data Set of the Luminaire.

In order to determine whether a particular LLE or LED Module is thermally compatible²² with a particular Luminaire, the user should verify that the applicable thermal resistance R_{th} specified in the Product Data Set of the Luminaire is less than or equal to the applicable maximum thermal resistance $R_{th,max}$ specified in the Product Data Set of the LLE or LED Module. Here, the applicable thermal resistance can be linearly approximated from thermal resistances corresponding to thermal powers above and below the actual LED Module thermal power. In cases of doubt or incomplete data, the thermal resistance of a power lower than the actual LED Module power shall be chosen for evaluation.

²¹ In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on the same heat sink the Reference Temperature of each LLE or LED Module depends on the characteristics of all LLEs or LED Modules and on the geometry of the system. In general this will result in a complex dependency matrix that cannot be translated into a simple model characterized by one thermal resistance (R_{th}). For that reason the model has been restricted to Luminaires with identical LLEs or LED Modules. In later editions of the document the model may be expanded to other configurations.

²² "thermally compatible" means that the LLE-Luminaire or LED Module-Luminaire combination will operate at $t_r \leq t_{r,max}$

The applicable maximum thermal resistance $R_{th,max}$ is the maximum thermal resistance that corresponds with the Ambient Temperature.

As an example (Informative), consider the information listed in the Product Data Sets of particular LLEs and Luminaires:

Data sheet of LLE #1					Data sheet of LLE #2				
$t_{r,max}$ (°C)	65				$t_{r,max}$ (°C)	80			
$P_{th,rear}$ (W)	18				$P_{th,rear}$ (W)	35			
t_a (°C)		30	40	50	t_a (°C)		30	40	50
$R_{th,max}$ (K/W)		1.9	1.4	0.8	$R_{th,max}$ (K/W)		1.4	1.1	0.9
Data sheet of Luminaire #1					Data sheet of Luminaire #2				
Max. t_a (°C)		30			Max. t_a (°C)		40		
R_{th} at $P_{th,rear} = 10$ W (K/W)		1.8			R_{th} at $P_{th,rear} = 10$ W (K/W)		0.9		
R_{th} at $P_{th,rear} = 20$ W (K/W)		1.6			R_{th} at $P_{th,rear} = 20$ W (K/W)		0.8		
R_{th} at $P_{th,rear} = 30$ W (K/W)		1.5			R_{th} at $P_{th,rear} = 30$ W (K/W)		0.7		
R_{th} at $P_{th,rear} = 40$ W (K/W)		1.4			R_{th} at $P_{th,rear} = 40$ W (K/W)		0.6		

From these numbers it can be concluded that

- LLE #1 is thermally compatible with Luminaire #1 as R_{th} at $P_{th,rear} = 10$ W (1,8 K/W) is less than $R_{th,max}$ at 30 °C (1,9 K/W)
- LLE #1 is thermally compatible with Luminaire #2 as R_{th} at $P_{th,rear} = 10$ W (0,9 K/W) is less than $R_{th,max}$ at 40 °C (1,4 K/W)
- LLE #2 is not thermally compatible with Luminaire #1 as R_{th} at $P_{th,rear} = 30$ W (1,5 K/W) is more than $R_{th,max}$ at 30 °C (1,4 K/W)
- LLE #2 is thermally compatible with Luminaire #2 as R_{th} at $P_{th,rear} = 30$ W (0,7 K/W) is less than $R_{th,max}$ at 40 °C (1,1 K/W)

6.2.8 Thermal uniformity

The thermal interface model defined in section 6.2.1 is a one-dimensional model. Implicitly it is assumed that the temperature across the Thermal Interface Surface is independent of the position. In typical applications this is not exactly the case. When replacing the LED Light Engine or LED Module by a Thermal Test Engine, the thermal interface model can only be used to predict the Reference Temperature if the temperature non-uniformity of the LED Light Engine or LED Module and the Thermal Test Engine are limited. The non-uniformity of the temperature distribution across the Thermal Interface Surface depends on:

- the construction of the LLE, TTE or LED Module and
- the construction of the heat sink of the Luminaire.

The non-uniformity of the temperature distribution across the Thermal Interface Surface is expressed in a set of thermal spreading resistance values. Here, the thermal spreading resistance between two measurement points i and j is defined as:

$$\text{EQ. 6-7: } R_{sp}(i,j) = \frac{t_i - t_j}{P_{th,rear}}$$

Here t_i and t_j are the temperatures at the measurement points i and j located on the Thermal Interface Surface. For each type of LLE or LED Module the positions of these measurement points may be defined in the respective Book.

The parameter R_{sp}^{max} is defined as the maximum value of all spreading resistance values:

$$\text{EQ. 6-8: } R_{sp}^{max} = \text{MAX}(R_{sp}(i,j))$$

The Zhaga interface specifications may restrict the thermal non-uniformity in the case of a LLE or LED Module being operated in a Test Fixture TUTF. For each type of LLE or LED Module the Test Fixture

TUTF and the requirements for thermal uniformity in this test case may be defined in the respective Book.

The Zhaga interface specifications may contain minimum requirements for the construction of the Luminaire. If so, these requirements are defined in the respective Book. If these requirements are not defined or not fulfilled, the Zhaga interface specifications may restrict the thermal non-uniformity in the case of a Thermal Test Engine being operated in a Luminaire. For each type of Luminaire the Thermal Test Engine and the requirements for thermal uniformity in this test case may be defined in the respective Book.

6.2.9 Thermal Interface Material

In order to guarantee good thermal contact between the LLE or LED Module and the heat sink, a Thermal Interface Material (TIM) is typically applied to this interface. The TIM is defined to be part of the LLE or LED Module and the Thermal Interface Surface is at the interface of the Luminaire and the TIM as depicted in Figure 6-3.

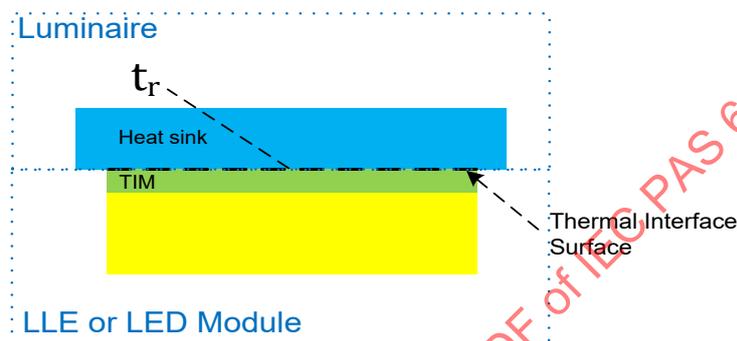


Figure 6-3: Position of the Thermal Interface Surface in case of a configuration with TIM

The LLE or LED Module shall be tested with the TIM prescribed by the LLE or LED Module manufacturer, and the LLE or LED Module manufacturer shall provide the prescribed TIM to the Zhaga Authorized Testing Center (ATC) when offering the LLE or LED Module for Zhaga certification. The Luminaire shall be tested with a TIM that is specified in the test specification of the respective Book.

6.2.10 Surface planarity and roughness

In order to guarantee good thermal contact between the LLE or LED Module and the heat sink of the Luminaire, both the surface of the LLE or LED module and the surface of the heat sink shall meet planarity and roughness requirements. For each type of LLE or LED Module these requirements may be defined in the respective Book.

6.2.11 Aging of LED Light Engine or LED Module (informative)

Due to aging of the LED, the radiated power (P_{vis}) will decrease over time and consequently the thermal power will increase. Although this effect is relatively weak it is recommended that the Luminaire manufacturer takes it into account in the design of the Luminaire.

6.2.12 Influence of the Electronic Control Gear on the thermal interface (informative)

In case of an LLE with Separate ECG, the thermal model described in section 6.2.1 does not take into account the influence of the thermal power of the ECG on the thermal interface. In this section guidelines are provided on how to deal with this simplification.

Due to the marginal influence of the ECG in most of the luminaires, Zhaga interface specifications do not specify a test for measuring the influence of the thermal power of the ECG on the thermal interface. In case of a Luminaire with an expected relatively high influence of the ECG on the thermal interface it is recommended to list in the Product Data Set a value of R_{th} which is 110% of the measured R_{th} . This will ensure that the Rated values of photometric parameters of Zhaga LLEs are met in all realistic circumstances.

Guideline for detecting Luminaires with a relatively high influence of the ECG on the thermal interface:

- LED Module and ECG are mounted on the same heat sink
- LED Module and ECG are mounted on different heat sinks but still influence each other by heating up the inner temperature of the Luminaire

6.2.13 Ambient Temperature and thermal resistance (R_{th}).

The Ambient Temperature is defined as the average temperature of the air in the environment where the Luminaire (or Test Fixture) is applied. A few typical examples are:

- In case of an outdoor Luminaire or a suspended indoor Luminaire, the Ambient Temperature is the temperature of the air in the vicinity of the Luminaire.
- In case of a recessed Luminaire, the Ambient Temperature is the temperature of the air in the room, below the ceiling and in the vicinity of the Luminaire.

In section 6.2.1, the thermal resistance of the Luminaire (R_{th}) is defined as the thermal resistance from the Thermal Interface Surface to the environment. The environment corresponds to the position where the Ambient Temperature is defined.

As a consequence of these definitions, the thermal resistance of the Luminaire (R_{th}) depends on the mounting conditions of the Luminaire. The Luminaire manufacturer defines in the PDS (generally in the mounting instructions) how the Luminaire shall be mounted. Next to that, the Luminaire manufacturer shall define a setup for measuring the thermal resistance of the Luminaire. This setup should be a good model for the actual application of the Luminaire. Note that this measurement setup can be anything ranging from a free air setup to measurement boxes as defined by, for example UL and IEC for safety tests. It is recommended to use the same test setup for R_{th} measurement as for safety measurement. The ATC will use the setup as defined by the Luminaire manufacturer to measure the thermal resistance of the Luminaire.